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FINAL REPORT

W-106-R

COOPERATIVE UPLAND WILDLIFE RESEARCH

Submitted by:

Cooperative Wildlife Research Laboratory, SIUC

Presented to:

Illinois Department of Conservation

December 1992

Prepared by:

John L. Roseberry, Senior Scientist
Cooperative Wildlife Research Lab.
Southern Illinois University
Carbondale, IL 62901

Approved by:

Alan Woolf, Director
Cooperative Wildlife Research Lab.
Southern Illinois University
Carbondale, IL 62901

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FINAL REPORT

STATE OF ILLINOIS

W-106-R, STUDIES 1, 3, 4, and 6

PROJECT PERIOD: 1 July 1989 - 30 June 1992

PROJECT TITLE: Cooperative Upland Wildlife Research

Prepared by John L. Roseberry
Cooperative Wildlife Research Laboratory
Southern Illinois University at Carbondale

Need:

For over a century, land use in Illinois has become progressively more intensive, especially with the advent of post-World War II farm technologies. Expanding row-crop production in recent decades has resulted in critical shortages of habitat for upland wildlife. In fact, the quality and quantity of upland wildlife habitat in Illinois is determined primarily by agricultural land use.

During the 1980's, problems of soil and water degradation associated with intensive row-cropping, and the chronic over-production of farm commodities, have gained wide recognition by the public. Recognition of these problems has precipitated legislation that provides emerging opportunities for integrating natural resource conservation goals with farm production programs. The 1985 Food Security Act put into place several conservation initiatives of potential importance for establishing upland wildlife habitat. Further, the "T by 2000" program in Illinois may provide opportunities for habitat development, as mandated soil and water quality goals are addressed.

These federal and state initiatives are likely to affect agricultural land use in Illinois for several decades. The challenge for natural resource agencies is to ensure that farm policies and programs accommodate the habitat needs of wildlife. Further, the Illinois Department of Conservation (IDOC) should establish and refine habitat programs that will extend the benefits of wildlife-components of farm programs.

Objectives:

The general objectives of this Project are to (1) describe important impacts and potential benefits of farm programs and policies on upland wildlife abundance in Illinois and (2) identify key land use practices that should be included in future farm programs and IDOC upland game habitat initiatives.

EXECUTIVE SUMMARY

This project was a cooperative effort involving the Illinois Department of Conservation, the Illinois Natural History Survey, and the Cooperative Wildlife Research Laboratory, Southern Illinois University at Carbondale (SIUC). Summaries of Findings and Conclusions from Jobs that were the responsibility of SIUC are reported in this Executive Summary. Full Job Completion Reports or equivalent manuscripts, with separate pagination, follow in the body of the Final Report. Objectives of Study No. 1, Job 1.1B (SIU) were met and reported in 2 manuscripts. Executive summaries of these are identified as Part 1 and Part 2.

STUDY NO. 1: **Effects of Emerging Farm Programs and Practices on Habitat Quality for Upland Game**

JOB 1.1B (SIU): **Upland Game Habitat Associations**

Objectives: (1) To document the effects of land-use changes (state-wide and regionally) on the abundance of northern bobwhite; and to (2) identify key land-use practices that should be included in future farm programs and IDOC habitat initiatives.

PART 1: SUMMARY OF FINDINGS AND CONCLUSIONS

1. Three indexes of bobwhite population trends over time (kill per unit effort, kill per area, and male call counts) were compared with amounts of existing CRP land at several resolutions including state, region, county, and local.

2. Some 256,260 ha in Illinois were enrolled in the CRP during the first 9 signup periods (1986-1989). This represented 4.0, 2.7, 2.3, and 1.0% of the South, Southcentral, Westcentral, and Northeast quail regions, respectively.

3. Approximately 87% of this CRP land in the state was enrolled in CP-1 contracts (introduced cool-season grasses and legumes). Only 1-2% was put into CP-2 (native warm season grasses) or CP-4 (wildlife habitat). Orchard grass, timothy, smooth brome, redtop, and tall fescue were the most commonly planted grasses in CP-1 fields. Alfalfa, Korean lespedeza, ladino clover, and red clover were the most common legumes.

4. Illinois quail populations declined from the mid to late 1970's, then began to recover in the early 1980's. They have remained relatively stable from the mid 1980's to the present. A significant amount of the annual variation in bobwhite

abundance can be accounted for by severity of the preceding winter and cycle phase.

5. Total hunting license sales declined sharply from the mid to late 1970's but have remained relatively stable during the 1980's. The trends in numbers quail hunters has been similar, but the relative decline has been steeper.

6. The CRP had no discernable impact on quail hunting effort in Illinois as measured by trips taken per individual hunter or total number of hunters.

7. Bobwhite population trends as measured by annual kill per trip and total harvest also seemed unrelated to amounts of CRP land present.

8. There was some suggestion that male bobwhite whistling counts in the South and Westcentral regions were positively affected by amounts of CRP land. However, this may have represented a local effect in which breeding birds were attracted to CRP fields in the vicinity of call routes.

9. Failure to demonstrate an unequivocal CRP effect on quail abundance in Illinois could be attributable to a) inadequate data, b) too little CRP land, or c) variable influence of CRP over time and space.

10. We conclude that CRP likely enhanced bobwhite habitat in some areas but these benefits were offset by neutral or negative effects in other places.

11. Over 93% of all CRP land in Illinois was planted to grass or a grass/legume mix and thus would potentially serve bobwhite only as nesting, brood rearing, or roosting cover. In areas were

winter food or cover were limiting, populations would likely not increase and might even decline if the replaced cropland had been an important winter food source.

12. Even in areas where reproductive habitat was limiting, potential CRP benefits might be limited by unfavorable vegetative composition or structure, or untimely disturbance such as mowing.

13. In retrospect, we conclude that the value of the CRP for bobwhite would have been enhanced if a) there had been less mowing, especially mid-summer mowing, b) strip discing and burning had been promoted to encourage more annual and perennial forbs, c) more land had been planted to CP-2 and CP-4 vegetation, and less in CP-1 cover, d) more CP-1 land had been planted to timothy/redtop/Korean lespedeza and less to tall fescue and orchard grass/clover mixtures, and e) more food had been provided in CRP fields by way of food plots or increased use of Korean lespedeza.

14. Enhancement of wildlife interests in future CRP or related conservation/agricultural initiatives will require action at the national, state, and local levels.

15. At the national level, there needs to be improved contract features designed to benefit specific species or communities of wildlife.

16. At the state level, cost-sharing and other land owner incentives should be implemented to the greatest extent possible to maximize opportunities for wildlife inherent in federal conservation/agricultural programs.

17. Locally, there needs to be a) greater awareness and

cooperation among ASCS/SCS officials regarding wildlife interests, b) more direct input from wildlife biologists, and c) more and better public information/education efforts.

18. Future cropland diversion programs may involve considerably less total acreage then the present CRP. Therefore, it is essential that potential benefits for wildlife be maximized. To do this, specific recommendations for individual species or communities must be made with knowledge of existing local and regional habitat conditions, especially limiting factors.

PART 2: SUMMARY OF FINDINGS AND CONCLUSIONS

1. Computer simulation and habitat modeling was combined with knowledge of actual spatial patterns of CRP fields and other land use types to investigate the potential contribution of CRP to local bobwhite habitat quality in Hamilton County, Illinois.

2. A classified Landsat V Thematic Mapper image (a product of Job 3.1A) was edited to include the location of every CRP field in the County (as of 1990).

3. The spatial relationship of CRP land with other habitat components and soil types was investigated with Geographic Information Systems (GIS) software.

4. A bobwhite habitat model (a product of Job 3.1A) was used to evaluate habitat quality with and without CRP land on a section by section basis.

5. Sections with no CRP land tended to be more intensively cultivated and less forested than did those with CRP acreage.

Consequently, CRP fields tended to be located in closer proximity to protective cover than did remaining cropfields.

6. Land enrolled in the CRP also tended to be situated in better bobwhite habitat than did land not enrolled or not eligible for the program.

7. Contribution of individual CRP fields to habitat quality depended on a) the amount of CRP land present, b) its suitability for bobwhite use, c) the suitability of replaced and remaining cropland for bobwhite use, d) the juxtaposition of CRP fields with other habitat components, and e) the composition and quality of existing bobwhite habitat, in particular the limiting factors.

STUDY NO. 3: **Bobwhite Habitat Evaluation in Relation to Farm Programs, Land-Use Practices and IDOC Habitat Initiatives**

JOB 3.1A (SIU): **Bobwhite Management Strategies**

Objectives: (1) To develop standardized methods for measuring and evaluating farmland bobwhite habitat over relatively large areas; and (2) to integrate this methodology into a management strategy for maximizing the potential contribution of farm program opportunities and management initiatives for enhancing bobwhite habitat.

SUMMARY OF FINDINGS AND CONCLUSIONS

1. This Job investigated the feasibility of acquiring land cover and habitat information over relatively large areas via remote sensing and analyzing it quantitatively with habitat models.
2. Methods for obtaining such information using aerial photography, video imagery, and satellite imagery were reviewed.
3. Classification and storage/manipulation of satellite imagery was briefly reviewed.
4. Existing bobwhite habitat models were reviewed with special attention given to features amenable for use with remotely-sensed data.
5. A digitized land cover image and data file of Hamilton County, Illinois was created using a combination of ground referencing, direct interpretation of high altitude color infrared photography, and supervised classification of a Landsat V Thematic Mapper scene (17 June 1989).
6. The final product was a 1.44 mb data file representing the land cover of Hamilton County, Illinois and a 0.8 km buffer zone

at 30 x 30 m ground resolution. Land use was categorized as intertilled cropland, small grain, grass/legume, deciduous forest, coniferous forest, hedgerow, oldfield, water, developed (urban, major roads), drainage, barren, and farmsteads.

7. Two bobwhite habitat models were developed to assess bobwhite habitat suitability on a landscape or larger scale based on amount and spatial distribution of land cover types discernable from remote sensing.

8. The models were modified to access a classified land cover database exported from a GIS program as an ASCII file, extract a user-defined area of interest, qualitatively and quantitatively assess habitat suitability, and identify limiting factors.

9. Model logic, structure, and equations are presented along with computer code for their implementation.

10. An adjunct corollary of this Job was the development of PC-based portable software which not only links classified land cover data bases with habitat models, but also facilitates interactive graphic display and manipulation of the data outside of the GIS environment. This prototype management-oriented system will be developed and expanded during Phase II of the Cooperative Upland Wildlife Research Project.

STUDY NO. 4: **Impacts of Farm Programs on Bobwhites**

JOB 4.1A (SIU): **ACR and CRP Seedings as Bobwhite Nesting and Brood-rearing Habitat**

Objectives: To compare and evaluate various ACR and CRP seedings as bobwhite breeding habitat; and (2) establish guidelines and recommendations for selection of specific practices to best meet bobwhite breeding habitat needs in particular areas or situations.

SUMMARY OF FINDINGS AND CONCLUSIONS

1. Field studies were conducted June-August, 1990 on the Jasper County Prairie Chicken Sanctuaries, Illinois.
2. Multiple nest searches were conducted on 10 separate fields (total 31 ha) representing cool-season grasses, native warm-season grasses, and oldfields.
3. Vegetative composition and structure was measured at each nest site and in randomly-located plots throughout each field.
4. Nesting bobwhites apparently selected for native warm-season grasses as more nests were found in these fields than would be expected based on availability.
5. Nesting birds apparently selected against redtop/timothy areas; however, this may have been because the fields were mowed annually.
6. Mid-successional oldfields that succeed from bare ground or intertilled cropland are usually considered prime bobwhite nesting cover. However, oldfields that succeed from pastures may retain a strong fescue component for many years and therefore provide inferior nesting habitat.
7. Bobwhite reproductive opportunities on CRP lands are

maximized when both brood rearing and nesting cover is provided. This can be accomplished by strip discing the field periodically, burning portions of the field on a rotational basis, or broadcasting grass seed so that there are alternating strips of grassy and weedy cover.

8. Recommendations to CRP land owners should promote the use of native warm-season grasses over introduced cool-season grasses.

9. If cool-season grasses are selected, a timothy/redtop/Korean lespedeza mixture is probably the preferred choice while tall fescue should be avoided if possible.

10. The comparative merits of smooth brome and orchard grass were not addressed by this study.

11. Including legumes in initial seedings or subsequent interseedings can increase diversity and insect abundance. However, dense stands of alfalfa or red clover are not conducive to bobwhite nesting.

12. Annual and perennial forbs should be encouraged either by incorporating native legumes in CP-2 seedings or by periodically strip discing CP-1 fields.

13. Mowing, especially during the peak nesting season (mid-May - mid-August) should be avoided.

14. Nesting/brood rearing cover is not always the limiting habitat component in every area. Where it is not, incorporation of food plots into CRP fields and greater use of Korean lespedeza should be encouraged.

STUDY NO. 6; JOB 6.1B (SIU): **Analysis and Reporting**

Objectives: (1) To computer-analyze and store important data sets; and (2) report the findings associated with Studies 1, 3, and 4.

The objectives of this Study were met with the submission of this Final Report plus preceding Annual Performance Reports.

STUDY NO. 1: **Effects of Emerging Farm Programs and Practices on Habitat Quality for Upland Game**

JOB 1.1B (SIU): **Upland Game Habitat Associations**

NEED:

Since World War II, intensive agricultural land use and associated farm programs have caused a qualitative and quantitative decline in upland wildlife habitat. Extending into the 1990's and beyond, upland game management strategies in Illinois must be structured within interacting components of farm policies. These components include (1) the long-term diverted acres program (CRP), (2) annual set-aside acres programs responsive to the short term supply and demand of farm commodities, and (3) widespread adoption of soil-saving practices such as rotation farming, grassy terraces, and minimal disturbance till/plant practices. As a first step toward developing improved habitat management plans and strategies, wildlife and habitat interactions need to be described and predicted on a regional basis.

OBJECTIVES:

(1) To document the effects of land-use changes (state-wide and regionally) on the abundance of northern bobwhite; and to (2) identify key land-use practices that should be included in future farm programs and IDOC habitat initiatives.

RESULTS

The results, conclusions, and recommendations from this Job are presented in the following 2 manuscripts.

THE CONSERVATION RESERVE PROGRAM AND NORTHERN BOBWHITE POPULATION TRENDS IN ILLINOIS

John L. Roseberry, Cooperative Wildlife Research Laboratory, Southern Illinois University-Carbondale, IL 62901

Larry M. David, Illinois Department of Conservation, Gibson City, IL 60936

The Conservation Reserve Program (CRP) of the 1985 Food Securities Act encouraged rural landowners to convert potentially erodible cropland to permanent cover (principally grasses) for a minimum of 10 years. From 1986 through 1989, some 13.7 million hectares (33.9 million acres) in the United States were enrolled in the program, representing 8% of the nation's cropland (Bjerke 1991). Although the CRP was primarily intended to reduce soil erosion and grain surpluses, potential benefits for wildlife were widely anticipated (Farmer et al. 1988, Isaacs and Howell 1988, Schenck and Williamson 1991). Among the species expected to benefit was the northern bobwhite (Colinus virginianus) (Burger et al 1990, Stauffer et al. 1990, Howell 1991). Over the past 25-30 years, this species has declined in abundance in Illinois and elsewhere due primarily to intensified agricultural land use (Kenney 1985, Brennan 1991).

Our objective was to assess the gross impact of the CRP on bobwhite abundance and secondarily, hunter effort in Illinois at the local, regional, and statewide level. We sought information that could enhance wildlife interests in future programs.

STUDY AREAS

We collected and analyzed data at 4 levels of resolution: statewide, regional, county, and local. For regional analysis, Illinois was divided into 4 contiguous areas (SOUTH, SOUTHCENTRAL, WESTCENTRAL, and NORTHEAST) using criteria of prevailing climate, land use, and estimated bobwhite densities (Fig. 1). Bobwhite population densities in the NORTHEAST region are quite low due to unfavorable climatic and land use conditions; therefore, only the SOUTH, SOUTHCENTRAL, WESTCENTRAL regions are emphasized in this report. Individual counties in these regions (n = 56) were ranked according to relative amount of CRP land and grouped into classes (LOW, MID, HIGH) representing the lower, middle, and upper 33 percentiles. Within each region, counties were grouped into LOWER and UPPER classes representing the lower and upper 50 percentiles.

METHODS

CRP Statistics

Total acreage enrolled in the CRP by county during signup periods 1-9 (1986-1989) was obtained from Agricultural Stabilization and Conservation Service (ASCS) records. Locations of individual CRP fields within 1.6 km of 32-km long transects within each of 46 counties were also obtained from ASCS offices, recorded on 1:12,600 scale black and white aerial photographs, and later digitized using the Map and Image Processing System (MIPS, Miller et al. 1989). Areal representation of the various Conservation Practices (CP 1-14) on CRP fields was obtained from Soil Conservation Service (SCS) data. Specific vegetative

plantings made under CP-1 (introduced grasses and legumes) provisions was determined by examining every 5th CP-1 contract at individual ASCS county offices (David et al. 1992).

Bobwhite Population Indexes

We used 3 indexes of bobwhite abundance: 1) estimated annual hunter harvest per square mile (KPA), 2) estimated harvest per hunter trip (KPT), and 3) time/area counts of male bobwhite calls in early summer (MBC). County, regional (1975-1991), and statewide (1974-1991) harvest data were obtained annually by the Illinois Department of Conservation (IDOC) from post-season questionnaires mailed to a random sample of resident hunting license holders (Anderson and Campbell 1991). Male bobwhite whistle counts were recorded by IDOC biologists annually from 1975-1991 along 46 semi-permanent routes located throughout the SOUTH, SOUTHCENTRAL, and WESTCENTRAL regions of Illinois. The 32-km transects consisted of 19-20 stops at about 1.6-km intervals. Each route was driven once per year in June on calm (wind <10 mph), relatively clear (<75% cloud cover) mornings and the total number of male bobwhite calls heard during a 2-minute listening period were recorded at each stop.

To assess the ability of these indexes to detect change over time, the minimum detectable difference (Zar 1984) at $\alpha = 0.10$ and power $(1 - \beta) = 0.90$ was computed for KPT and MBC using 1990 and 1991 data. When survey data were lumped, the smallest detectable annual change in KPT in the SOUTH, SOUTHCENTRAL, and WESTCENTRAL regions and STATEWIDE was approximately 57, 24, 24, and 16%, respectively. Minimum detectable differences for KPT at

the county level ranged from 60 to >150%. Although confidence limits for county and regional estimates of KPA were not computed, they were undoubtedly higher then for KPT. The smallest detectable annual change for MBC (dependent samples) in the SOUTH, SOUTHCENTRAL, and WESTCENTRAL regions and STATEWIDE was approximately 27, 11, 11, and 8%, respectively. At the county level, minimum detectable differences averaged about 49% (median = 42%). We concluded that pooled harvest data could be used to detect temporal trends (up, down, stable) among groups of counties but not individual counties, whereas the more precise call count index could be interpreted (with caution) at the individual route (county) level.

Bobwhite Hunter Effort

Two indexes of hunter effort were computed from IDOC post-season hunter surveys. These were the average number of trips taken by each reporting quail hunter (TPH) and the estimated total number of quail hunters per unit area (HPA).

Environmental Parameters

Daily maximum and minimum temperatures and total precipitation were obtained from 59 weather stations throughout Illinois for the period 1973-91 (U.S. Dept. Commerce, 1973-91). Number of days of snow cover ≥2.54 cm per month was available from a representative subset of these stations. From these data, a series of temperature, precipitation, evapotranspiration, and snow cover parameters were computed for 23 biologically significant periods of the calendar year.

A variable indexing a potential temporal bobwhite population cycle (Roseberry and Klimstra 1984) was obtained from the Nautical Almanac (1973-90) using methods described by Archibald (1977).

Land Use Patterns

Land cover types (16 categories) within a 0.8 km-wide corridor along each call count route were identified and mapped by IDOC biologists during field inspections in early summer 1991. Land use information was originally recorded on 1:12,600 scale aerial photographs and later converted to computer map images and digital data files to facilitate analysis. Eight routes (207 km^2) were surveyed in the SOUTH, 25 routes (648 km^2) in the SOUTHCENTRAL, and 15 routes (389 km^2) in the WESTCENTRAL regions.

Data Analysis

Simple correlation analysis was used initially to investigate relationships between individual weather parameters and the various abundance indexes. Multiple regression analysis (MLR) was then used to assess the statistical effect of CRP on regional and statewide bobwhite abundance indexes (KPA, KPT, MBC) during the years 1974-1991 (1975-1991 for MBC). The amount of variance accounted for ($\underline{R}^2$) by cycle phase, the previous winter's snow cover, and hunter effort (for KPA) was determined for each abundance index. The estimated percentage of land area in CRP vegetation during each growing season was then added to these models to determine if there was a significant ($\underline{P} < 0.10$) increase in $\underline{R}^2$.

Trends in bobwhite abundance also were examined specifically for the years immediately preceding and following implementation of the CRP (1985-1991). PROC GLM (SAS Institute Inc. 1985) was used to perform nested Analysis of Variance (ANOVA) for unbalanced data. CONTRAST statements were used to test the specific hypothesis that linear trends over time did not differ among groups of counties with relatively low, medium, and high amounts of CRP ($\alpha = 0.10$). Separate AVOVAs were run for KPT, KPA, and MBC.

Mean male bobwhite call counts (MBC) for individual routes were regressed on time (1985-1991) to determine the presence and direction of temporal change. Because of the small number of years involved ($\underline{n} = 7$), a liberal α of 0.30 was accepted as indicating change. The frequency of directional change (up, down, even) was then compared among call routes grouped according to amount of CRP land within a 0.4 and 1.6 km of each route and within 0.4 km of each listening stop using X^2 in contingency tables ($\alpha = 0.10$).

Regional trends in indexes of abundance were also compared between groups of counties with above- and below-average amounts of CRP by computing and plotting a ratio of the 2 groups during the period 1982-1991.

RESULTS

CRP Participation

Approximately 256,260 ha in Illinois were enrolled in the CRP during the first 9 signup periods (1986-90) (Appendix A). This figure represented 1.8% of the state's total area, 2.6% of

its cropland, and 13.3% of all eligible land (Table 1). Areal representation ranged from 0% in Cook and DuPage counties to 9.0% in Hamilton County. The SOUTH region ranked first in terms of total area (4.0%), cropland (9.9%), and eligible land (30.2%) enrolled in CRP and the NORTH region ranked last with 1.0%, 1.3%, and 8.4%, respectively. The relative amounts of CRP land in the various comparative county groupings are shown in Table 2.

The percentage of total statewide CRP land established in vegetation during the growing seasons of 1985 to 1991 was approximately 0, 5, 29, 57, 80, 100, and 100%, respectively, based on timing and response to individual signups (Fig. 2). This pattern showed minimal regional variation. Nearly 87% of CRP land was initially placed in the CP-1 category (introduced cool-season grasses and legumes) (Appendix B). This figure ranged from 80% in the NORTH region to 92% in the SOUTHCENTRAL region (Table 3). Specific seedings made under CP-1 contracts varied considerably by region. In the SOUTH, the most commonly planted species and the percentage of total CP-1 acreage they occurred on were ladino clover, Trifolium repens, (61.4%); orchard grass, Dactylis glomerata, (58.8%); and tall fescue, Festuca arundinaceae (40.3%). Commonly used cover mixtures were orchard grass/ladino clover, orchard grass/Korean lespedeza (Lespedeza stipulacea), and tall fescue monocultures. In the SOUTHCENTRAL region, Korean lespedeza occurred on 49.9% of the CP-1 acreage followed by timothy, Phleum pratense, (47.1%), redtop, Agrostis alba, (41.1%), and orchard grass (38.0%). Commonly used mixtures were redtop/timothy/Korean lespedeza,

orchard grass/ladino clover, and orchard grass/Korean lespedeza. Tall fescue appeared on 25.5% of the CP-1 acreage in the SOUTHCENTRAL region. In Hamilton County though, which ranked first and third in the state in terms of relative and absolute amounts of CRP, fescue was planted on 78% of all CRP land. In the WESTCENTRAL region, the most common CP-1 species were orchard grass (60.9%), alfalfa, Medicago sativa, (57.0%), smooth brome grass, Bromus inermis, (37.4%), and timothy (32.4%). Common mixtures were alfalfa/orchard grass, alfalfa/smooth brome grass, and alfalfa/timothy/orchard grass.

CRP in Relation to Other Habitat Components

Land use composition along call count routes is summarized by Region in Table 4. The relative amount of CRP land within 0.4 km of routes in the SOUTH, SOUTHCENTRAL, AND WESTCENTRAL regions was 3.9, 3.4, and 2.0%, respectively. These figures are reasonably comparable to the region-wide enrollment estimates of 4.0, 2.7, and 2.3%, respectively (Table 1). In the SOUTH region, the amount of land occupied by CRP was equivalent to 11% of the land in forest, 16% of the existing cropland, and 19% of other grasslands. Comparable figures in the SOUTHCENTRAL and WESTCENTRAL regions were 19, 4, and 28% and 15, 4, and 15%, respectively.

Effect of CRP on Indexes of Bobwhite Abundance and Hunter Effort

Statewide.--Temporal trends (1974-1991) for the 3 indexes of bobwhite abundance (KPT, KPA, MBC) were relatively similar at the statewide level (Fig. 3). Populations declined substantially

from the mid to late 1970's, then began to recover in the early 1980's. By the late 1980's, KPT and MBC had regained or exceeded former levels, but KPA had not. Similar trends were evident among individual regions except that the relative ranking of the SOUTH Region in relation to the SOUTHCENTRAL and WESTCENTRAL declined with respect to KPA and MBC. Total hunting license sales declined sharply from the mid- to late-70's, then remained relatively constant throughout the remainder of the period; the estimated number of quail hunters showed a similar pattern (Fig. 4).

The 2 environmental variables that were most consistently correlated with indexes of bobwhite abundance at the statewide and regional levels where cycle phase and duration of snow cover the previous winter (Appendix C). In combination, these variables explained 65% of the annual variation in KPT at the statewide level ($\underline{R}^2 = 0.653$, $\underline{P} < 0.001$), 51% for KPA ($\underline{R}^2 = 0.514$, $\underline{P} = 0.004$), and 48% for MBC ($\underline{R}^2 = 0.481$, $\underline{P} = 0.010$). When the estimated number of hunters was included as a predictor of KPA, $\underline{R}^2$ increased to 0.879 ($\underline{P} < 0.001$).

The relative amount of CRP land plus knowledge of previous winter weather and cycle phase explained a significant portion of the total variance in annual KPT ($\underline{P} = 0.076$) and MBC ($\underline{P} = 0.022$), but not KPA ($\underline{P} = 0.986$) during the period 1974-1991 (Appendices D, E, F). However, when KPT and MBC trends were compared among counties grouped according to relative amounts of CRP, no significant differences were evident (Appendix G). In agreement with these statistical findings, a visual plot of composite

indexes for each group gave no indication of a positive (or negative) effect for CRP (Fig. 5-A,C). Counties grouped according to relative amounts of CRP did exhibit significantly different KPA trends (Appendix G). However, KPA tended to decline in counties with the most CRP land while remaining stable or increasing in counties with lesser amounts of CRP (Fig. 5-B). Similarly, hunting effort as measured by hunter density (HPA) and trips per hunter (TPH) tended to decline in those counties with the most CRP while remaining stable or increasing in counties with lesser amounts (Fig. 6).

Regional.--Multiple regression analysis of the SOUTH region indicated no CRP effect (either positive or negative) on KPT (P = 0.59), KPA (P = 0.39), or MBC (P = 0.20) (Appendices H, I, J). In agreement, the ANOVA indicated that 1985-1991 changes in KPT, KPA, and MBC did not differ between counties with above- and below-average amounts of CRP (Appendix K). However, a visual plot of the data from 1982 through 1991 showed that KPA in counties with below-average amounts of CRP increased in relation to counties with above-average amounts whereas MBC declined (Fig. 7-B and C). In other words, there was a suggested negative CRP effect on KPA and a positive CRP effect on MBC.

In the SOUTHCENTRAL region, the MLR analysis (Appendices L, M, N) indicated a significant or suggestive positive association between amounts of CRP land and annual variation in KPT (P = 0.08) and MBC (P = 0.11), but not KPA (P = 0.98). In contrast, the ANOVA showed a negative CRP effect on KPA (P = 0.002) but no

effect on KPT and MBC ($\underline{P} > 0.56$) (Appendix O). This finding was also indicated by a visual plot of the data (Fig. 8).

In the WESTCENTRAL region, MBC variability during 1975-1991 was associated ($\underline{P} = 0.009$) with CRP (Appendix R) but no such effect was indicated for KPT or KPA (Appendix P and Q). Corroborating evidence was obtained from the ANOVA which revealed a significant ($\underline{P} < 0.001$) time x CRP class interaction for MBC (Appendix S) and a plot of the 1982-1991 trends which showed MBC in above-average CRP counties increasing in relation to below-average counties (Fig. 9-C).

When hunter effort was examined by individual region, there was no indication of a positive CRP effect on either TPH or HPA (Figs. 10).

County and Local.--Data from 46 individual call count routes were examined to identify possible county and local CRP effects. During 1985-1991, MBC increased along 13 routes, declined for 16, and remained relatively unchanged for 17. Frequency of change was compared among routes classified according to relative amounts of CRP in their respective counties and within 0.4 and 1.8 km of the route and 0.4 km of individual stops. Group memberships using these different criteria were very similar. No relationships were evident when data were pooled over all regions (Table 5). Similar contingency tables could not be constructed for individual regions because of insufficient cell sizes. The possible positive CRP effect on MBC in the SOUTH and WESTCENTRAL regions (Figs 7-C and 9-C) may have reflected local rather than county-wide effects as those counties with the greatest amounts

of CRP land also tended to have the most CRP land in close proximity to the call count routes and stops. It is possible that breeding birds were attracted to CRP fields in the vicinity of call count routes.

Most of the counties in the 3 major bobwhite regions had relatively small amounts of CRP land. Five counties, however, contained substantial amounts ($\geq$ 8%); these were Hamilton, Jefferson, Franklin, Union, and Johnson. Call counts remained essentially unchanged from 1985 to 1991 in 3 of these counties but declined ($P < 0.05$) in 2 adjacent counties with the most CRP land (Jefferson and Hamilton). CP-1 contracts predominated in both counties (94-98%) with fescue the most common CP-1 seeding in Hamilton County (78%) and timothy/redtop/Korean lespedeza (94.5%) in Jefferson County.

DISCUSSION

In order to properly evaluate bobwhite population performance, it is necessary to distinguish between short-term fluctuations and long-term trends (Roseberry and Klimstra 1984). The former are related primarily to periodic weather perturbations and possible cyclic phenomena, whereas the latter are mainly a function of land use/habitat conditions. The success of individual quail hunters as measured by their kill per unit effort may reflect short-term fluctuations better than long-term trends. This supposition is based on the assumption that up to a point, experienced quail hunters would be able to identify and exploit areas of suitable habitat even if the overall habitat base was declining. While also reflecting short-term changes in

abundance, the total numerical harvest may be related more to total available habitat (and hunter effort), and therefore may be a better indicator of long-term trends in bobwhite abundance. The relationship between male call counts and seasonal population densities has been discussed by numerous workers (see review by Roseberry and Klimstra, 1984:103). Those authors concluded that male call counts were primarily related to early summer population density but may also be partially indicative of relative breeding activity. If so, the index would be expected to vary with both short-term weather events and long-term habitat trends.

We examined multiple indexes of quail abundance and hunter effort including kill per unit effort (KPT), kill per unit area (KPA), effort per individual hunter (TPH), relative hunter density (HPA), and early summer male bobwhite whistling counts (MBC). With minor exception, KPT, KPA, and MBC performed similarly during 1974-1991. Each experienced a sharp decline in the late 1970's, followed by a general recovery in the early 1980's, and a period of relative stability during the remainder of the decade (Fig. 3). The major difference was that kill per unit effort (KPT) and male whistling counts (MBC) ultimately regained or surpassed initial levels whereas total harvests (KPA) did not.

Roseberry and Klimstra (1984) reported that annual variation in bobwhite abundance on a local area in southern Illinois from 1953-1979 was related to duration of snow cover the previous winter and a cyclic phenomenon of unknown origin. The present

study, which examined the period 1974-1991, also demonstrated a negative relationship between bobwhite abundance and duration of snow cover the previous winter. A cyclic component consistent with that described by Roseberry and Klimstra (1984) was also suggested by the data.

Multiple regression analysis indicated that a significant portion of statewide KPT and MBC variance from 1974(75) through 1991 could be accounted for by inclusion of CRP into the predictive model. However, such an apparent statistical relationship, especially in a time series, does not necessarily imply a cause and effect relationship. Problematical too was the fact that only the latter 5 years in the series had appreciable amounts of CRP. When trends in bobwhite abundance for more recent years (1985-1991) were compared among counties grouped according to relative amount of CRP, the only evidence of a positive CRP effect was on MBC in the Westcentral region.

There was general expectation among wildlife officials that the CRP would benefit open land wildlife species, especially in situations where nesting/brood rearing cover was limiting (Jahn 1988, Jahn and Schenck 1991). However, with the possible exception of call counts in the SOUTH and WESTCENTRAL regions, our study revealed no conclusive or consistent evidence that the CRP had a measurable effect on bobwhite population trends in Illinois during the period 1985-1991. Two possibilities may exist to explain this finding: (1) the study design and/or data were not adequate to demonstrate either a positive or negative CRP effect, or (2) there was no overall positive or negative CRP effect.

We concluded that available data (with the possible exception of MBC) were insufficient to assess bobwhite population trends at the county level. We believe, though, that when pooled over a several counties, the data (especially KPT and MBC) were adequate to identify temporal trends. However, the necessity to pool county data limited the opportunity to consider factors other than gross amounts of CRP land (e.g., Conservation Practices, mowing regimes, etc). It is generally preferable to test *a priori* hypotheses with carefully-designed experimentation rather than make *a posteriori* comparisons from retrospective observations. However, the latter approach was necessitated by the nature and scope of the question addressed in this study, i.e., did CRP enrollment under provisions of the 1985 Farm Bill have a measurable impact on bobwhite abundance in Illinois at the local, regional, or statewide level. Based on the available data, we conclude that it did not.

Assuming that data and methodologies were adequate, there could be several reasons for the absence of a demonstrable CRP effect (positive or negative) on regional or statewide bobwhite abundance in Illinois (at least through 1991): (1) the amount of affected land in relation to the total habitat base was too small to have a significant impact, (2) suitability of individual fields changed over time so that their contribution was positive for only a portion of the study period, or (3) suitability varied spatially so that positive effects in some localities were offset by neutral or negative effects in others.

Regarding the first possibility, habitat modeling and simulations based on conditions in Hamilton County suggested that CRP fields of average or poor suitability for bobwhite would have relatively little overall impact on habitat quality when CRP land constituted < 6% of the total area (Roseberry et al. 1992). Regionally, CRP land constituted 4.0% of the SOUTH region land area, 2.7% of the SOUTHCENTRAL region, and 2.3% of the WESTCENTRAL region. Of the 56 counties in these regions, 38 (68%) contained < 3.0% CRP land and 24 (43%) had < 2.0%. Five counties in the SOUTH and SOUTHCENTRAL regions did, however, contain relatively large amounts of CRP land (> 8.0% of their total land area). In addition, CRP land probably comprised a somewhat larger proportion of the extant habitat base than the total land area because cropland enrolled in the program was more frequently located in areas of existing bobwhite habitat than fields not enrolled (Roseberry et al. 1992). Nevertheless, it is perhaps unrealistic to assume the CRP could have exerted a major impact on bobwhite abundance at the regional or statewide level given the relatively small amount of land involved. The suggested positive CRP effect on MBC in the SOUTH and WESTCENTRAL regions may have reflected a local effect. Composition of the county groups representing high and low amounts of CRP was very similar regardless of whether based on amount of county-wide CRP land or CRP land in the immediate vicinity of the call route.

Another factor complicating the evaluation of CRP as bobwhite habitat is that the contribution of individual fields to particular needs would change over time as vegetative composition

and structure changed (Burger et al. 1990). The staggered entry of fields into the program and variable rates of succession would make it virtually impossible to address this retrospectively on a regional scale. However, these same circumstances should theoretically help ensure the continued existence of a desirable mix of vegetative conditions.

A more likely explanation of the apparent lack of an overall CRP effect on bobwhite abundance is that the contribution of individual fields varied spatially so that beneficial effects in some localities were offset by neutral or negative effects in others. Stauffer et al. (1990:66) recognized this possibility and noted that: "When the conversion of cropland to CRP increases the overall habitat diversity within an area and adds components previously lacking (such as nesting and brood-rearing cover provided by CP-1), we can expect to see an increase in quail populations. Conversely, when overall diversity is reduced, quail populations are likely to decline." Burger et al. (1990:82) expressed a similar opinion: ". . . the CRP will not be uniformly good or bad for quail. The value of these grass fields will depend on the availability of other cover types in the immediate vicinity of the CRP field." Roseberry et al. (1992:9) concluded that CRP contribution to bobwhite habitat would depend on "a) the amount of CRP land present, b) its suitability for bobwhite use, c) the suitability of replaced and remaining cropland for bobwhite use, d) the juxtaposition of CRP fields with other habitat components, and e) the composition and quality of existing bobwhite habitat, in particular the limiting factors."

In Illinois, > 93% of the land enrolled in CRP during the first 9 signups was planted to grass or a grass/legume mix and would therefore be potentially useful to bobwhites primarily as nesting, brood rearing, or roosting cover. Thus, even though individual CRP fields might have received considerable seasonal use by bobwhites, total population densities would likely not have increased in areas where food or protective cover were limiting. Even where nesting/brood rearing habitat was limiting, the addition of CRP land would not necessarily have been universally beneficial due to unsuitable vegetation or excessive or untimely disturbance or a combination.

Burger et al. (1990) suggested that CP-2 (warm-season grasses) and CP-4 (wildlife habitat) fields were superior to CP-1 vegetation (cool season grasses and legumes) for bobwhite. However, only 3.5% of the CRP land in Illinois was committed to these CPs while 86.9% was put into CP-1. The latter commonly featured tall fescue, orchard grass, or orchard grass/legume mixes, the suitability of which is generally considered only fair to poor for bobwhite nesting/brood rearing (Martin 1988). The most potentially useful, commonly recommended CP-1 planting is probably timothy/redtop/Korean lespedeza which is generally rated as good for bobwhite nesting and brood rearing cover (Martin 1988).

Even when vegetative composition of CRP fields is potentially suitable for bobwhite, use is often severely limited by mowing activities. In northern Missouri, Burger et al. (1990:82) considered mowing to be a "major factor limiting

habitat quality of CRP lands." As much as 40% of Illinois CRP fields may be subject to seasonal mowing (David et al. 1992). Midsummer mowing may actually turn some CRP fields into ecological traps where nesting birds and/or broods are initially attracted, then either killed by mowing or forced into inferior habitat where mortality from other causes is increased.

In addition to bobwhite abundance, we also examined trends in quail hunter opportunities and effort for possible relationships with the CRP. Over the past 15 years, hunting license sales in Illinois declined ≈ 30% while the number of quail hunters declined > 42%. Reduced interest in quail hunting can probably be traced to a number of factors including dropouts during the severe weather-related lows of the late 70's, increased difficulty in finding a place to hunt, and increased popularity of deer hunting (gun and bow) and other outdoor activities such as competitive fishing. Langer (1989:388) compared total CRP enrollment in relation to estimated amounts of existing habitat and concluded that the CRP would have: ". . . little impact on total habitat availability, and therefore [would result in] . . . few new entrants into the hunting population." Instead, she predicted that it would result in ". . . additional days of small game hunting from existing hunters." In Illinois, however, neither the estimated number of quail hunters, nor their average days afield changed significantly during the period of potential CRP influence (1985-1991). In a 1991 survey of 834 Illinois quail hunters, 34.4% said they had hunted on CRP land, 46.2% said they had not, and 19.4% did not know (Anderson and

David, 1992). Of those individuals who had hunted on CRP land, 63.4% believed the program had benefited quail populations, 3.9% thought it hurt, 11.4% said it had no effect, and 21.3% did not know. These findings differ somewhat from results of a 1990 survey of 127 quail hunters in southern and westcentral Illinois in which response to the same question was helped, 46.5%; hurt, 14.2%; no effect, 20.5%; and don't know, 18.9% (Roseberry 1992). This latter survey was not limited to hunters who said they had hunted on CRP land.

CONCLUSIONS AND RECOMMENDATIONS

Under certain circumstances, CRP lands undoubtedly make a positive contribution to local bobwhite habitat. In other situations, however, they probably contribute little or nothing and may even be detrimental. This, coupled with the fact that CRP land comprises a relatively small proportion of the total habitat base, are thought to be the principal reasons why regional and statewide Illinois bobwhite population levels did not respond positively to the CRP, at least through 1991.

Brennan (1991:552) characterized the CRP as a "lost opportunity" because potential benefits for northern bobwhite were not fully realized. The merits of the CRP cannot, of course, be judged solely on its contribution to a single species. Other wildlife species and communities must also be considered along with the primary mission of reducing soil erosion and grain surpluses (Young and Osborn 1990). Nevertheless, we agree with Brennan (1991) that the program could have benefited northern bobwhite much more than it apparently did. In retrospect, we

believe the following would have measurably enhanced the value of the CRP for quail:

1. Reduction or elimination of mowing activities, especially mid-summer mowing.
2. Encouragement of more weedy vegetation through strip discing and controlled burning.
3. More enrolled land in CP-2 and CP-4 vegetation and less in CP-1.
4. More use of timothy/redtop/Korean lespedeza seedings in CP-1 fields and less use of tall fescue, orchard grass/clover mixtures.
5. More provision of food in the form of food plots or Korean lespedeza seedings.

Greater promotion and implementation of wildlife interests in future CRP or related conservation/agricultural programs will require action at the national, state, and local levels. Cook (1989) noted 3 areas that need to be addressed nationally to ensure improved wildlife performance of the CRP or similar future programs: a) improvement of contract features to enhance wildlife, b) targeting enrollment to areas of special significance for wildlife, and c) development of longer term retirement programs, probably involving conservation easements. At the state level, cost-sharing and other land owner incentives need to be implemented to the greatest possible degree to maximize opportunities for wildlife inherent in federal conservation/agricultural programs. Locally, there needs to be a) greater awareness and more cooperation among ASCS/SCS

officials regarding wildlife interests (Miller and Bromley 1989), b) more direct input from wildlife biologists regarding specific practices to benefit wildlife (e.g. White 1992), and c) greater efforts to inform and educate participating land owners regarding available cost/sharing opportunities (Kurzejeski et al. 1992).

The future of the CRP as it now exists is unclear. Contracts on the oldest fields will begin to expire in 1996 and significant acreages could be lost by 1998. The fate of fields currently enrolled is uncertain, but many will likely be returned to cropland while others will probably be hayed or grazed (Carek 1988). In any event, it is probable that the acreage of relatively undisturbed perennial vegetation will be substantially reduced. For this reason, efforts should be directed toward maximizing the potential contribution of these areas to wildlife. To do this, it is essential that the juxtaposition of retired land to other cover types be considered (Langer 1989) and that specific management recommendations be cognizant of existing local and regional habitat conditions, especially components or life requisites that appear to be limiting (Roseberry et al. 1992).

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Table 1. Regional and statewide CRP enrollment in Illinois during signups 1-9 (1986-1989).

	Percent of		
Region	Total Area	Cropland[a]	Eligible Land[a]
South	4.01	9.93	30.16
Southcentral	2.71	4.15	15.74
Westcentral	2.26	3.18	14.79
Northeast	0.96	1.32	8.40
Statewide	1.77	2.64	13.30

[a] Agricultural Stabilization and Conservation Service figures.

Table 2. CRP statistics and county membership for study groups.

		Percent of Area Enrolled	
Group	N	Mean	Range
Low[a]	17	0.97	0.20 - 1.69
Mid[b]	17	2.43	1.72 - 3.18
High[c]	16	5.68	3.57 - 9.02
South-Below[d]	5	1.91	0.20 - 3.18
South-Above[e]	6	5.60	3.57 - 8.65
Southcentral-Below[f]	12	1.18	0.45 - 2.20
Southcentral-Above[g]	11	4.82	2.27 - 9.02
Westcentral-Below[h]	8	1.37	0.64 - 2.13
Westcentral-Above[i]	8	3.40	2.13 - 5.33

[a] Alexander, Clinton, Crawford, Effingham, Fulton, Gallatin, Jasper, McDonough, Macoupin, Madison, Montgomery, Morgan, Richland, St. Clair, Wabash, Washington, White.

[b] Adams, Brown, Cass, Clay, Edwards, Greene, Hancock, Hardin, Jackson, Jersey, Lawrence, Monroe, Perry, Randolph, Saline, Schuyler, Scott.

[c] Bond, Calhoun, Fayette, Franklin, Hamilton, Jefferson, Johnson, Marion, Mason, Massac, Pike, Pope, Pulaski, Union, Wayne, Williamson.

[d] Alexander, Gallatin, Hardin, Jackson, Saline.

[e] Johnson, Massac, Pope, Pulaski, Union, Williamson.

[f] Clay, Clinton, Crawford, Effingham, Jasper, Madison, Perry, Richland, St. Clair, Wabash, Washington, White.

[g] Bond, Edwards, Fayette, Franklin, Hamilton, Jefferson, Lawrence, Marion, Monroe, Randolph, Wayne.

[h] Brown, Fulton, Jersey, McDonough, Macoupin, Montgomery, Morgan, Schuyler.

[i] Adams, Calhoun, Cass, Greene, Hancock, Mason, Pike, Scott.

Table 3. Major Conservation Practices employed on CRP land in Illinois during signups 1-9 (1986-1989).

	Percent of CRP land in				
Region	CP1[a]	CP2[b]	CP3[c]	CP4[d]	CP10[e]
South	83.00	0.42	2.43	1.12	10.90
Southcentral	92.24	1.32	2.23	0.98	1.85
Westcentral	89.91	0.76	1.21	2.19	3.20
Northeast	79.95	2.01	4.01	4.47	7.77
Statewide	86.93	1.25	2.53	2.23	5.16

[a] Introduced grasses and legumes.

[b] Native grasses.

[c] Trees.

[d] Wildlife habitat.

[e] Already in grass.

Table 4. Percent land use composition along Illinois bobwhite call count routes, 1991.

	Land Use Type						
Region	Forest	Intertilled Cropland	Small Grain	Forage	CRP	Idle	Other
South	38.0	23.6	2.1	20.6	3.9	4.9	6.9
Southcentral	14.0	53.3	11.5	9.6	3.4	2.7	5.5
Westcentral	14.8	54.5	6.2	15.3	2.0	2.0	5.2

Table 5. Frequency of change in male bobwhite whistling count (MBC) vs. amount of CRP land within 1.6 km of route, 1985-1991.

	Male Bobwhite Whistling Count (MBC)			
CRP Class	Increase	Stable	Decrease	Total
High	3	6	6	15
Medium	5	6	5	16
Low	5	5	5	15
Total	13	17	16	46

X^2 = 0.825, df=4, $\underline{P}$ = 0.935

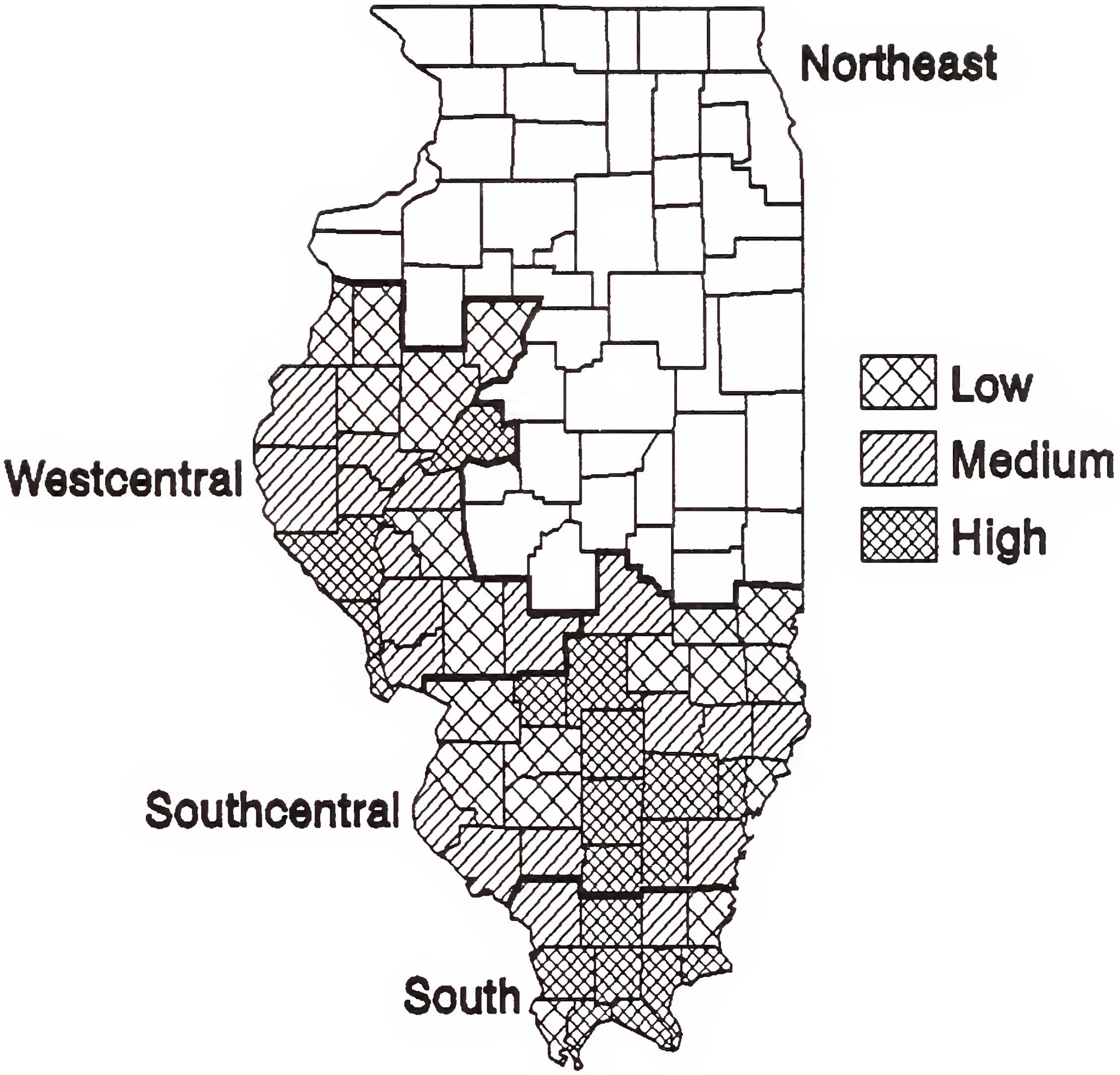

Figure 1. Major bobwhite regions in Illinois, and counties with low, medium, and high amounts of CRP land, 1990.

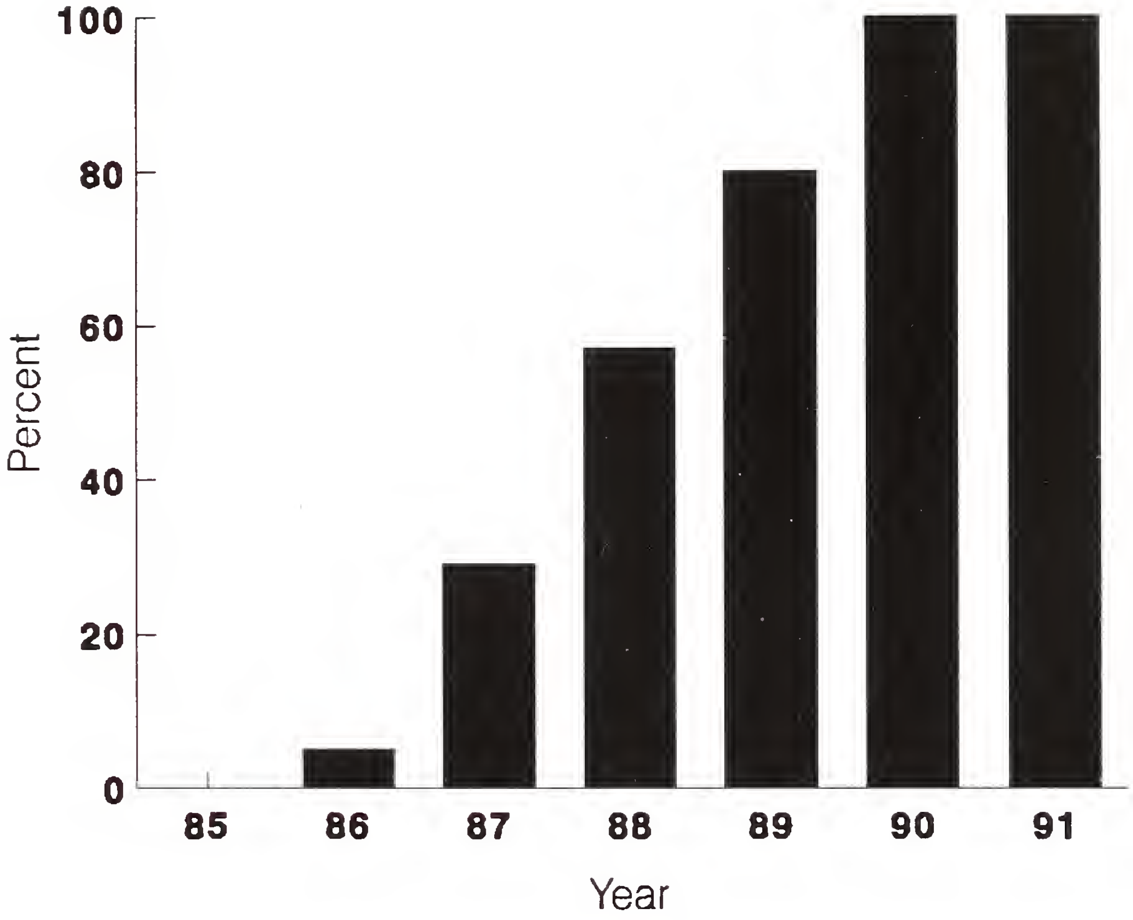

Figure 2. The yearly percentage of total CRP land extant during 1985-1990., Illinois.

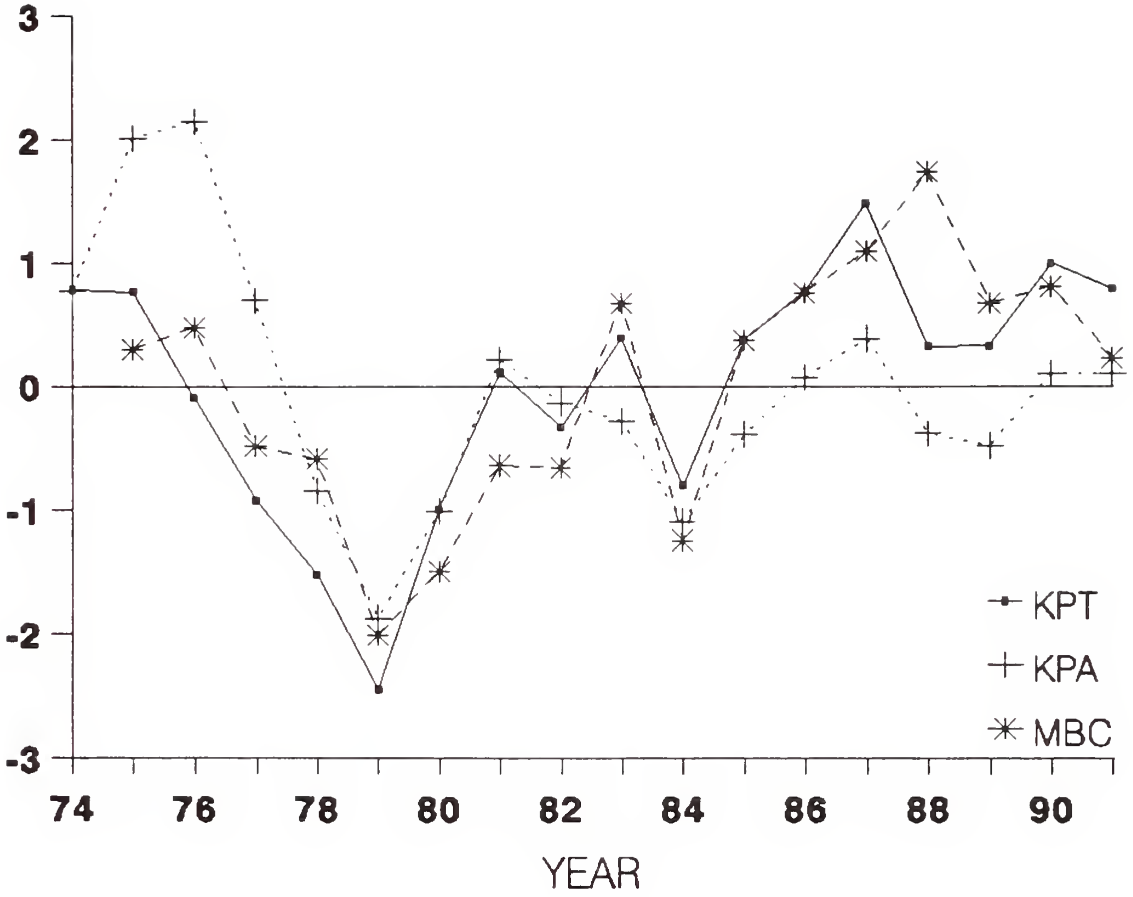

Figure 3. Trends in bobwhite abundance indexes in Illinois, 1974-1991. Y-axis represents standardized scores.

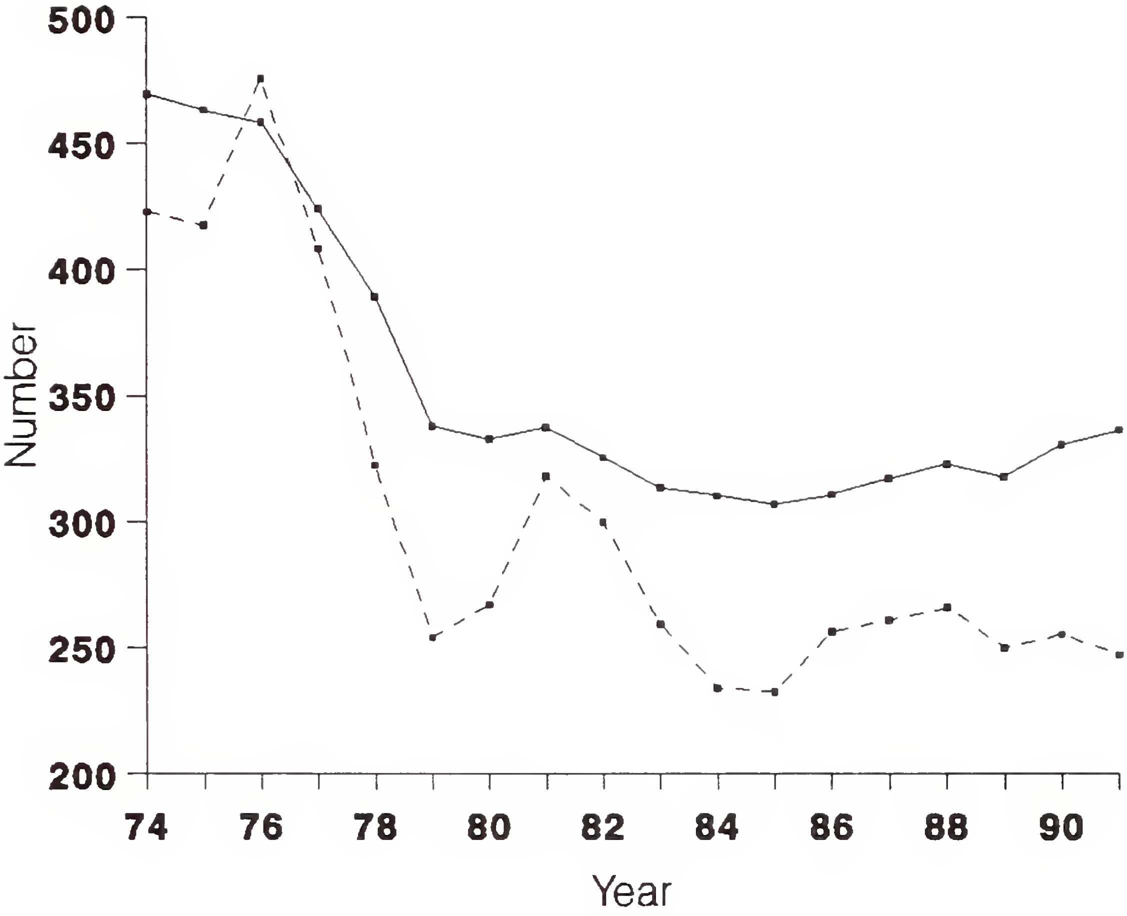

Figure 4. Trends in total hunting license sales (x1000) and quail hunters (x3000) in Illinois, 1974-1991.

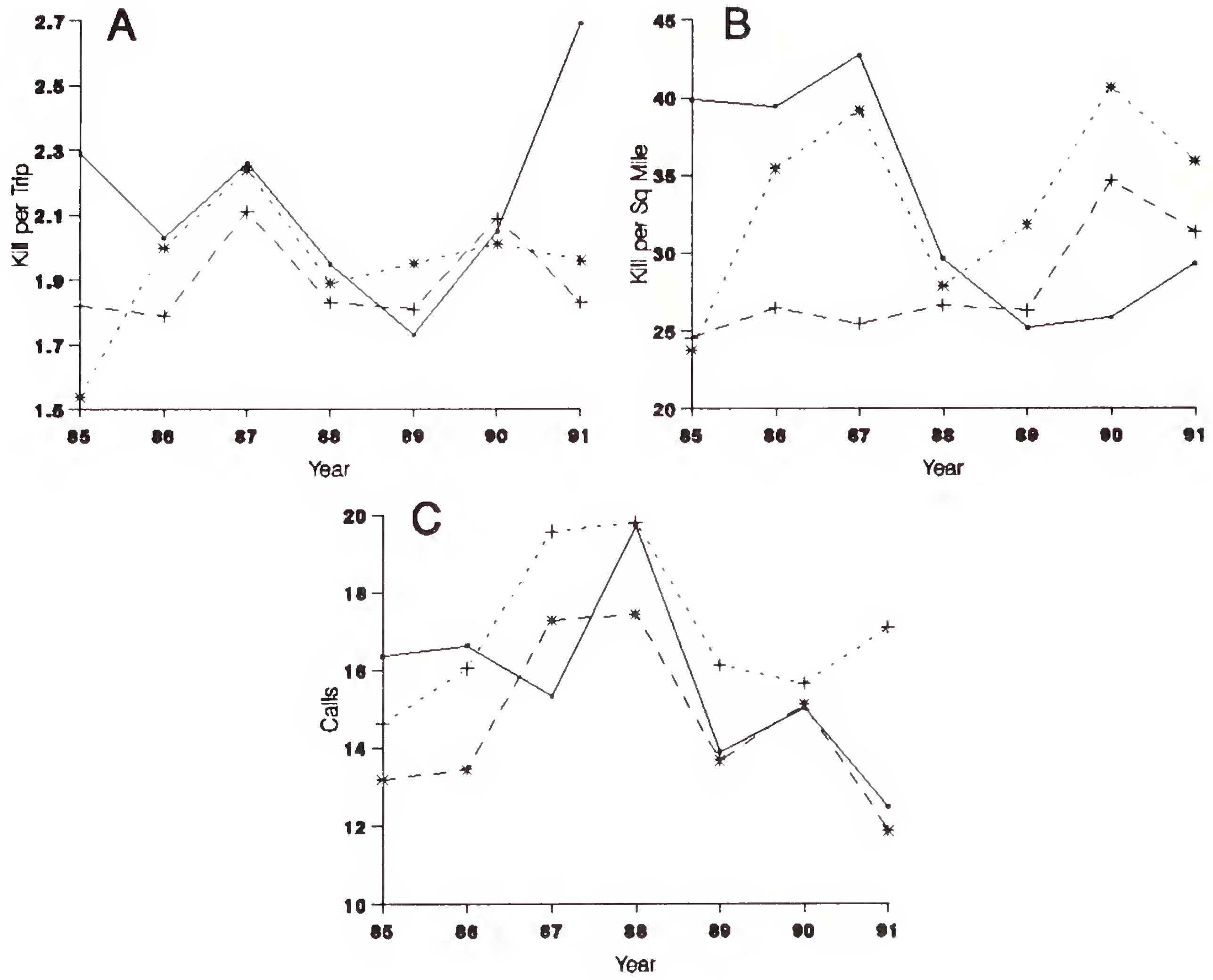

Figure 5. Trends in kill per trip (A), kill per area (B), and male calls (C) for Illinois counties with low (dotted), medium (dashed), and high (solid) amounts of CRP, 1985-1991.

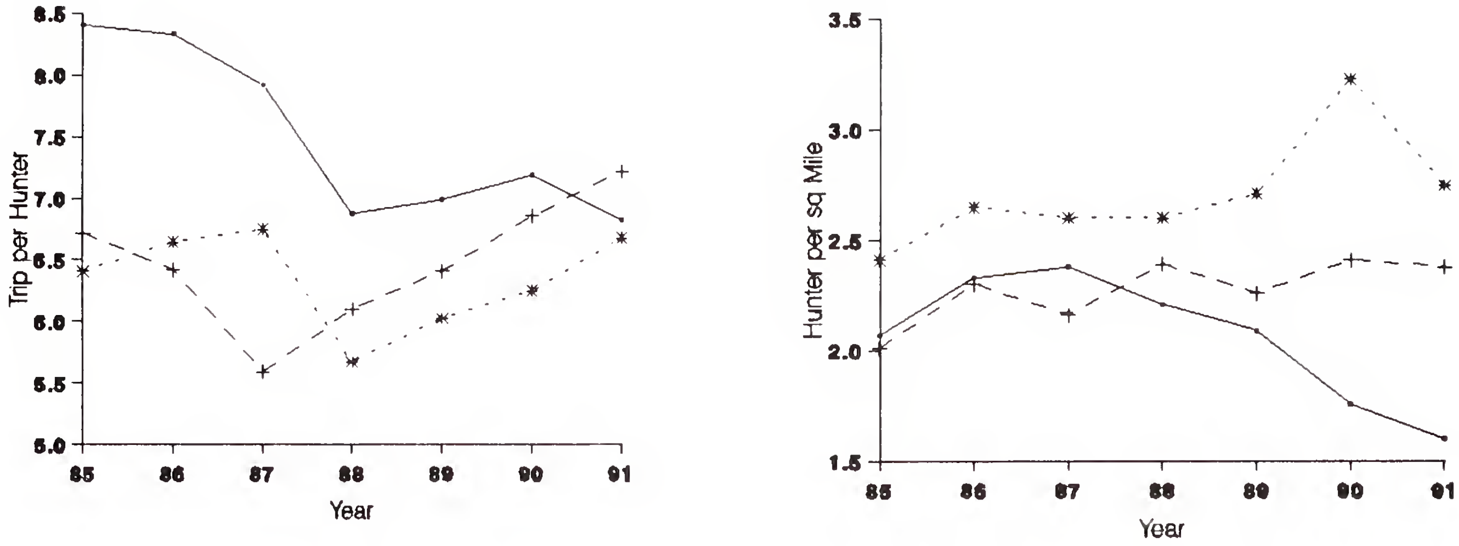

Figure 6. Trends in trips per hunter (left) and hunters per square mile (right) for Illinois counties with low (dotted), medium (dashed), and high (solid) amounts of CRP, 1985-1991.

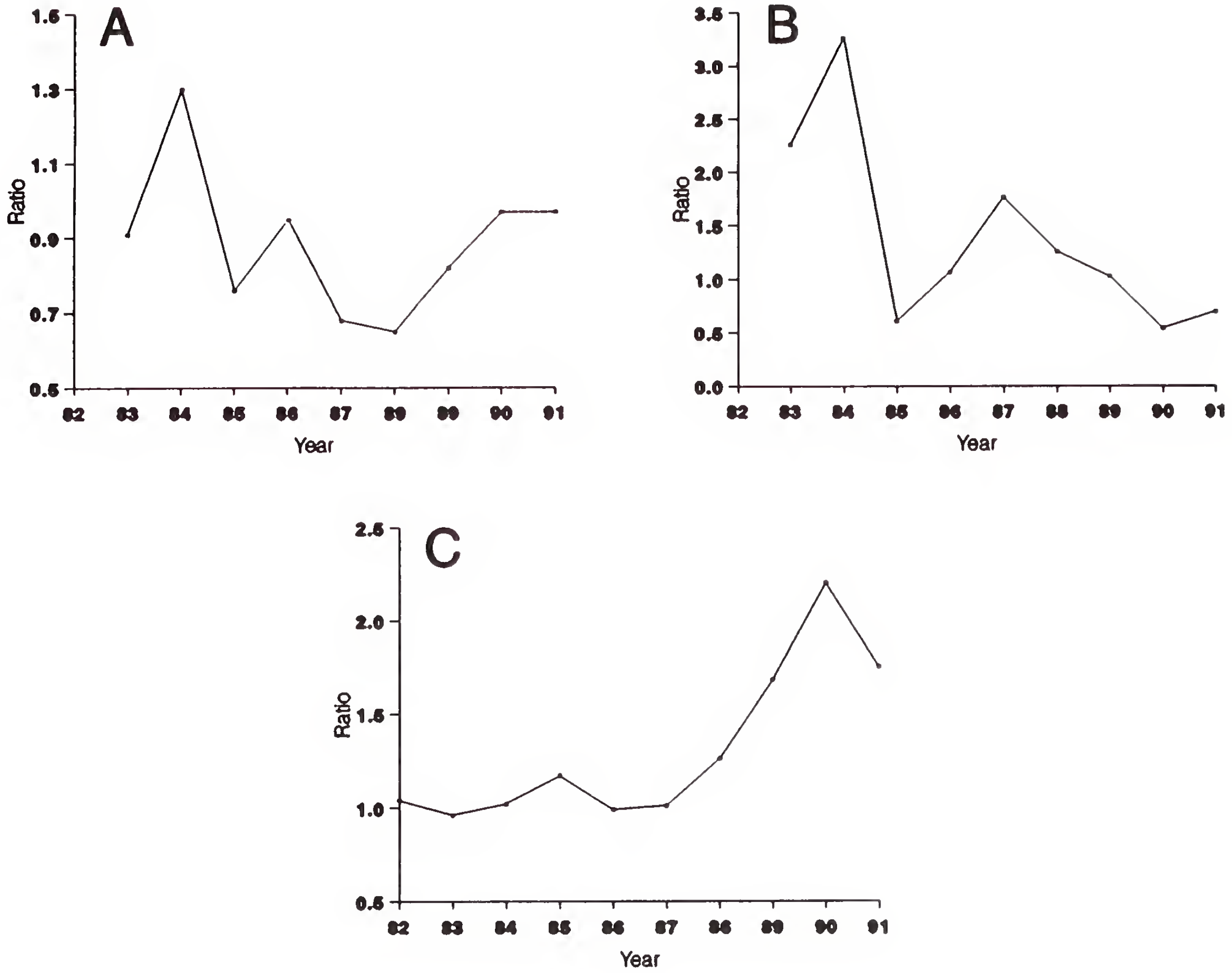

Figure 7. Comparative ratio of above-average/below-average CRP counties for kill per trip (A), kill per area (B), and male calls (C), South region, Illinois, 1982-91.

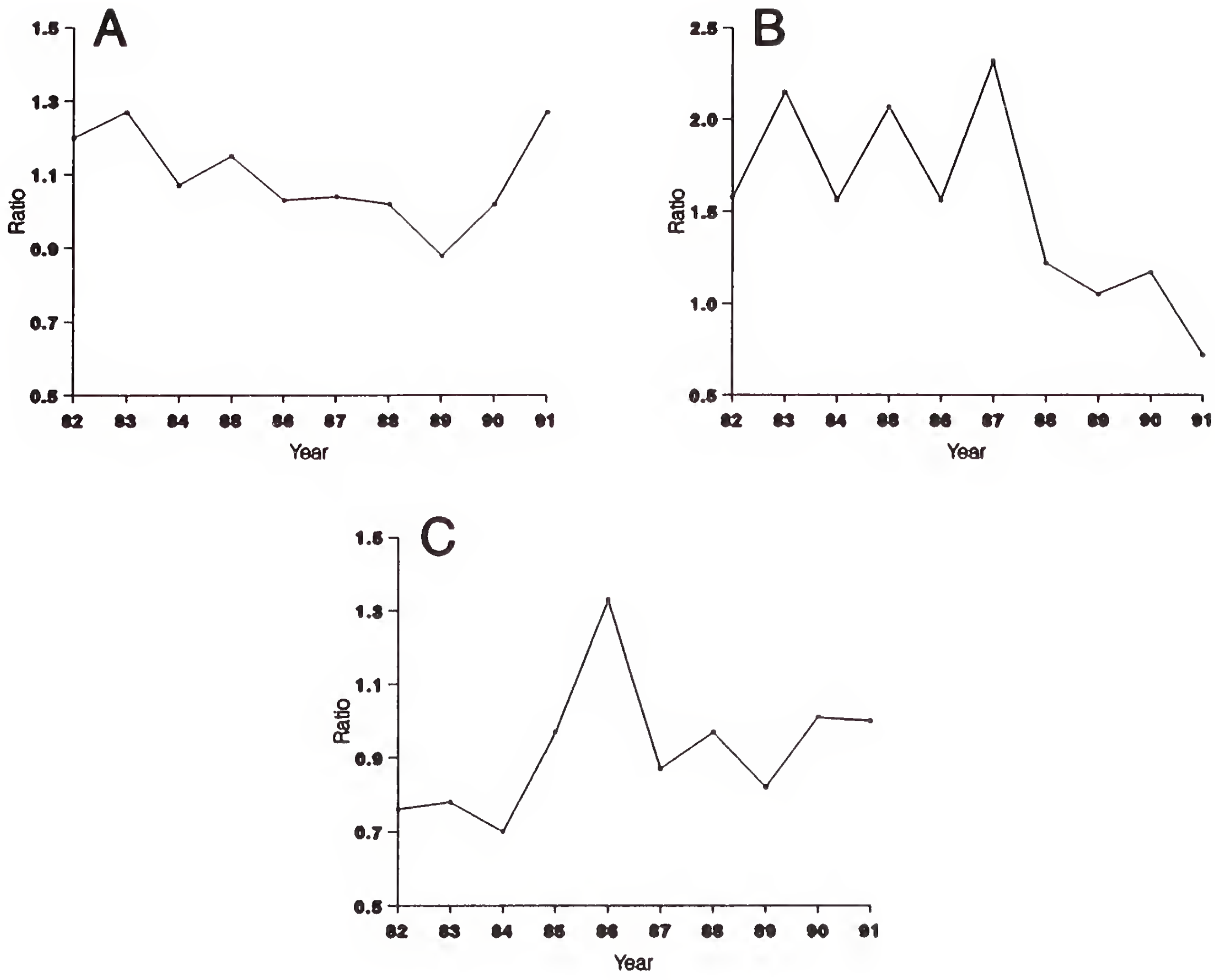

Figure 8. Comparative ratio of above-average/below-average CRP counties for kill per trip (A), kill per area (B), and male calls (C), Southcentral region, Illinois, 1982-91.

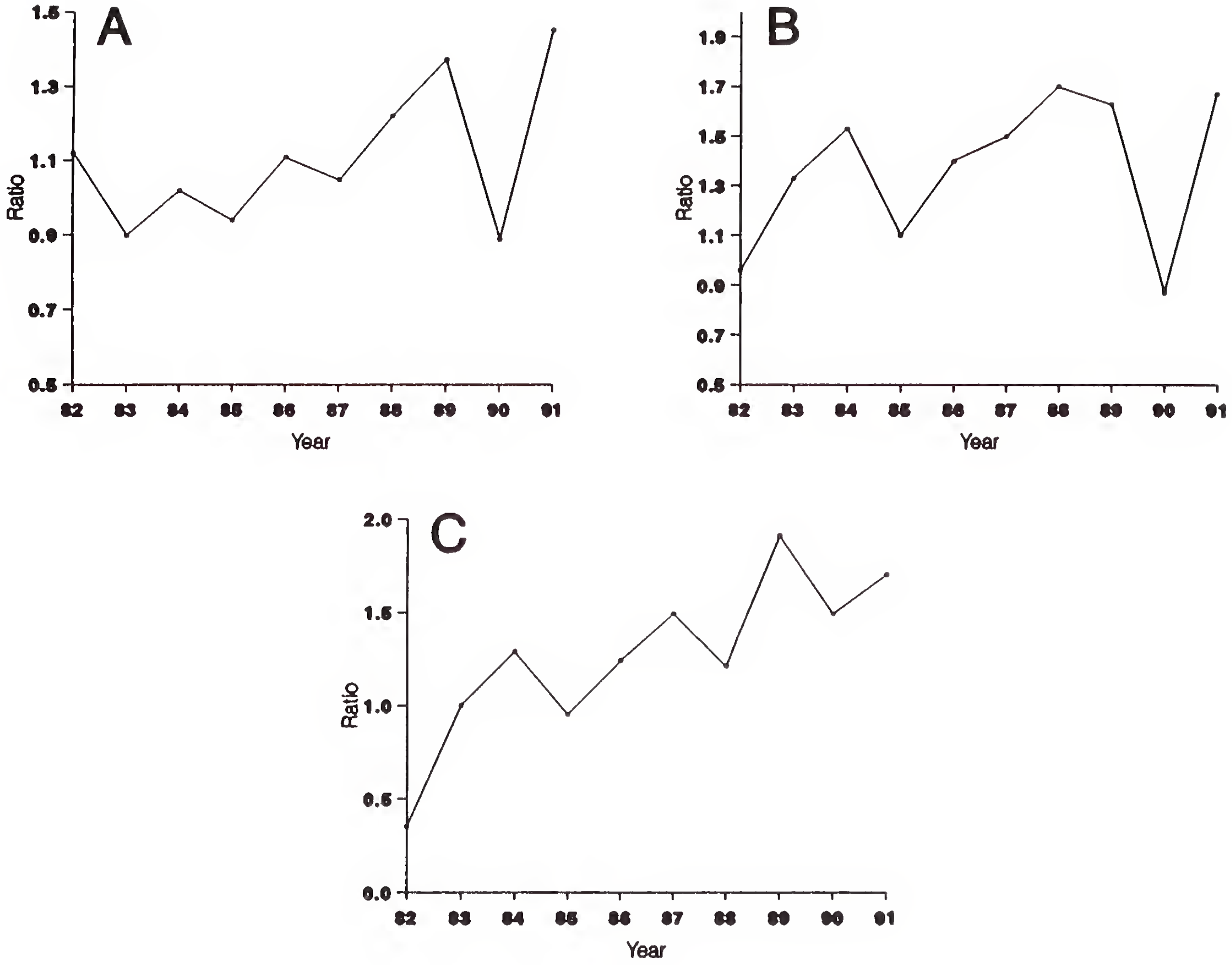

Figure 9. Comparative ratio of above-average/below-average CRP counties for kill per trip (A), kill per area (B), and male calls (C), Westcentral region, Illinois, 1982-91.

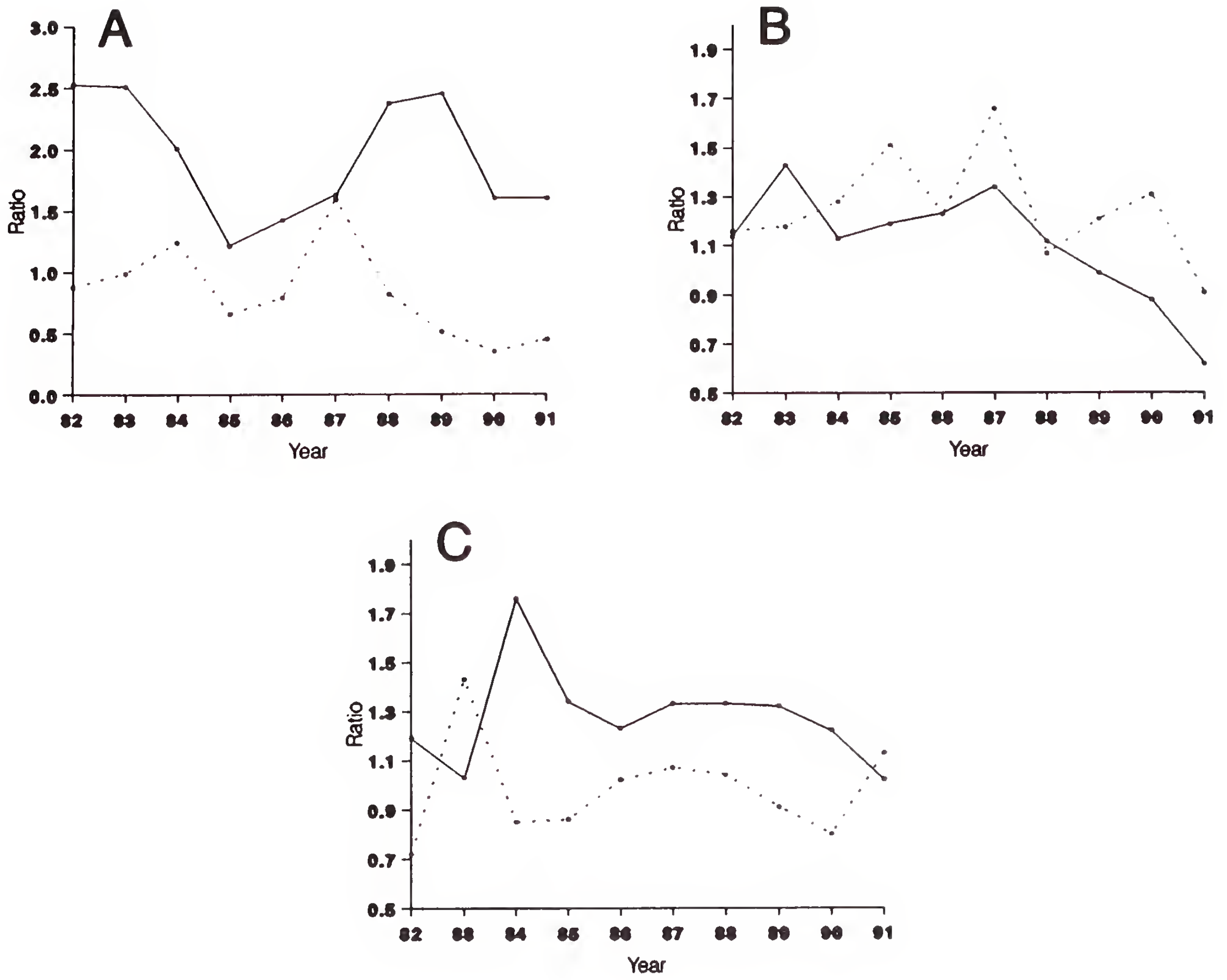

Figure 10. Comparative ratio of above-average/below-average CRP counties for trips per hunter (dashed line) and hunter density (solid line) in South (A), Southcentral (B), and Westcentral (C) regions, Illinois, 1982-91..

Appendix A. Illinois County CRP enrollment (ha) during signup periods 1-9, March 1986 - August 1989.

County	Signup Period 1	2	3	4	5	6	7	8	9	Total
ADAMS	127	130	251	1,849	1,055	1,064	721	405	639	6,241
ALEXANDER	13	0	0	18	14	10	0	12	51	118
BOND	3	27	171	1,143	401	275	582	428	602	3,632
BOONE	22	31	11	562	156	21	23	54	93	973
BROWN	23	124	245	118	148	318	283	144	295	1,698
BUREAU	70	62	35	1,553	191	369	162	141	310	2,893
CALHOUN	47	255	88	1,048	55	447	199	363	478	2,980
CARROLL	37	0	63	1,215	239	118	323	735	517	3,247
CASS	14	88	31	214	147	1,085	296	442	181	2,498
CHAMPAIGN	0	6	16	132	10	147	123	327	238	999
CHRISTIAN	36	0	21	68	26	32	65	193	127	568
CLARK	2	0	0	38	19	26	35	28	20	168
CLAY	40	94	243	556	74	105	382	815	332	2,641
CLINTON	0	8	26	190	44	3	193	68	139	671
COLES	24	132	64	77	149	178	102	78	141	945
COOK	0	0	0	0	0	0	0	0	0	0
CRAWFORD	6	1	10	70	130	70	38	127	66	518
CUMBERLAND	9	20	64	248	100	40	26	22	46	575
DEKALB	0	0	0	380	204	30	1	14	18	647
DEWITT	0	0	17	30	34	17	62	26	26	212
DOUGLAS	0	0	0	125	5	13	32	86	76	337
DUPAGE	0	0	0	0	0	0	0	0	0	0
EDGAR	134	91	182	623	90	275	473	774	679	3,321
EDWARDS	146	38	53	260	72	68	338	420	368	1,763
EFFINGHAM	13	13	70	327	123	59	35	104	166	910
FAYETTE	34	74	285	1,686	864	817	273	2,324	401	6,758
FORD	6	6	17	393	61	40	62	72	243	900
FRANKLIN	290	586	830	2,722	795	685	1,900	1,260	572	9,640
FULTON	124	81	204	503	126	289	139	119	196	1,781
GALLATIN	76	42	216	385	131	134	0	40	4	1,028
GREENE	100	84	192	1,915	198	313	74	42	919	3,837
GRUNDY	0	0	0	193	0	0	0	0	0	193
HAMILTON	312	560	922	2,016	1,212	930	1,488	1,552	1,172	10,164
HANCOCK	163	566	382	1,270	365	549	350	463	296	4.404
HARDIN	23	382	172	384	143	110	87	0	206	1,507
HENDERSON	4	0	0	153	24	2	59	29	80	351
HENRY	60	74	103	1,395	164	375	164	779	838	3,952
IROQUOIS	8	23	26	295	234	120	194	459	741	2,100
JACKSON	167	104	340	1,745	663	276	412	217	251	4,175
JASPER	2	34	70	140	102	141	206	100	74	869
JEFFERSON	620	611	1,830	3,970	1,340	1,382	606	1,081	1,455	12,895

Appendix A. Continued.

County	Signup Period 1	2	3	4	5	6	7	8	9	Total
JERSEY	15	171	97	368	252	228	310	278	289	2,008
JO DAVIES	104	72	431	1,940	611	813	768	1,042	1,196	6,977
JOHNSON	273	821	929	2,331	328	747	694	940	0	7,063
KANE	0	8	28	27	4	25	0	0	14	106
KANKAKEE	16	0	87	117	26	8	9	4	57	324
KENDALL	3	0	0	58	0	23	19	42	34	179
KNOX	34	10	0	581	195	198	402	134	288	1,842
LAKE	0	0	0	26	0	0	0	0	0	26
LASALLE	31	32	136	691	223	331	304	841	681	3,270
LAWRENCE	0	16	109	547	134	428	486	232	420	2,372
LEE	14	0	4	598	42	62	47	17	155	939
LIVINGSTON	73	53	40	506	72	421	382	501	1,061	3,109
LOGAN	32	3	6	134	26	49	31	85	50	416
MCDONOUGH	42	87	106	425	43	73	71	84	183	1,114
MCHENRY	24	7	101	510	134	16	93	197	140	1,222
MCLEAN	151	88	179	670	293	252	155	823	642	3,253
MACON	3	23	8	115	57	72	34	11	77	400
MACOUPIN	49	93	55	849	361	561	295	251	310	2,824
MADISON	19	53	133	579	105	224	270	239	188	1,810
MARION	344	410	690	1,111	606	324	1,416	616	782	6,299
MARSHALL	8	8	11	84	28	30	10	28	48	255
MASON	186	151	365	1,878	633	1,114	690	682	584	6,283
MASSAC	42	125	142	1,556	249	467	129	131	83	2,924
MENARD	8	16	6	191	142	80	113	285	49	890
MERCER	24	49	68	1,452	317	152	132	249	256	2,699
MONROE	0	47	75	572	183	405	60	769	191	2,302
MONTGOMERY	25	2	62	1,270	295	360	340	256	412	3,022
MORGAN	33	25	35	162	31	171	141	221	124	943
MOULTRIE	14	7	14	110	14	48	28	11	10	256
OGLE	59	15	255	2,005	498	347	497	361	626	4,663
PEORIA	0	3	13	93	64	121	72	38	17	421
PERRY	69	177	153	556	193	182	157	216	658	2,361
PIATT	0	3	29	126	2	30	126	108	136	560
PIKE	696	1,249	985	3,520	508	996	350	1,105	2,031	11,440
POPE	339	495	958	1,235	330	120	151	255	34	3,917
PULASKI	0	52	485	1,004	258	169	224	166	210	2,568
PUTNAM	7	0	41	20	10	15	0	15	57	165
RANDOLPH	25	13	68	722	432	284	668	586	694	3,492
RICHLAND	23	46	150	296	59	152	371	193	302	1,592
ROCK ISL.	0	12	44	597	117	44	225	329	567	1,935
ST. CLAIR	3	25	204	332	159	107	204	138	129	1,301
SALINE	148	74	202	595	144	298	395	333	112	2,301

Appendix A. Continued.

	Signup Period									
County	1	2	3	4	5	6	7	8	9	Total
SANGAMON	31	27	31	304	22	178	453	124	618	1,788
SCHUYLER	24	48	120	562	138	272	168	109	493	1,934
SCOTT	110	4	65	153	152	120	369	200	556	1,729
SHELBY	124	175	188	793	261	430	431	362	578	3,342
STARK	9	0	52	163	22	87	115	261	130	839
STEPHENSON	13	10	16	1,386	355	692	103	678	467	3,720
TAZEWELL	4	0	39	233	90	157	80	178	153	934
UNION	363	667	1,598	3,038	174	987	1,446	479	524	9,276
VERMILION	17	21	54	736	149	85	99	277	422	1,860
WABASH	0	0	20	257	122	53	77	158	69	756
WARREN	0	18	20	341	2	26	71	100	121	699
WASHINGTON	27	19	164	363	159	151	304	165	586	1,938
WAYNE	355	507	747	2,207	1,028	774	1,342	977	1,740	9,677
WHITE	30	44	311	421	58	89	375	241	310	1,879
WHITESIDE	0	10	103	826	111	62	386	699	730	2,927
WILL	0	178	28	326	66	154	58	228	124	1,162
WILLIAMSON	114	265	493	1,420	446	225	297	429	243	3,932
WINNEBAGO	40	43	121	877	150	149	187	239	242	2,048
WOODFORD	23	4	9	259	84	171	106	89	119	864
TOTALS	6,978	10,930	18,932	75,234	21,675	26,345	27,842	33,149	35,176	256,261

Appendix B. Percent of total CRP land in various Conservation Practices by individual Illinois county, signups 1-9, 1986 - 1989.

County	Conservation Practice[a]													
	1	2	3	4	5	6	7	8	9	10	11	12	13	14
ADAMS	90.7	0.0	0.3	0.0	0.0	0.5	0.5	0.1	0.0	6.8	0.0	0.0	0.7	0.4
ALEXANDER	72.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	22.2	3.8	0.0	1.4	0.3
BOND	95.0	0.0	0.7	0.3	0.0	0.0	0.0	0.0	0.0	2.5	0.0	0.1	1.4	0.0
BOONE	95.1	0.8	2.9	0.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.5	0.0
BROWN	96.4	0.0	1.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.2	1.0
BUREAU	95.5	0.0	1.3	2.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.7	0.3
CALHOUN	80.1	2.6	0.9	3.6	0.0	0.1	0.4	0.0	0.4	5.7	0.0	0.2	0.8	5.5
CARROLL	75.7	0.4	2.7	10.0	0.0	0.0	0.0	0.0	0.0	11.1	0.0	0.0	0.0	0.0
CASS	95.3	0.0	0.4	0.7	0.0	0.8	1.3	0.0	0.0	0.8	0.1	0.0	0.6	0.0
CHAMPAIGN	73.7	0.5	20.0	0.0	0.0	0.0	0.0	0.0	0.0	0.5	0.0	0.0	5.2	0.0
CHRISTIAN	89.1	1.6	5.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2	3.4	0.0
CLARK	85.6	1.5	9.7	0.0	0.0	0.0	0.0	0.0	0.0	0.7	0.0	0.0	0.7	1.7
CLAY	74.6	6.3	9.9	4.9	0.0	0.0	0.0	0.0	0.0	0.7	0.0	0.0	2.2	1.5
CLINTON	77.2	1.1	3.8	2.9	0.0	0.0	0.1	0.1	0.1	5.9	0.0	0.5	1.9	6.2
COLES	86.0	0.2	5.5	2.8	0.0	0.0	0.0	0.1	0.0	0.3	0.0	0.0	2.3	2.9
COOK	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
CRAWFORD	94.3	0.0	1.9	2.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2	1.6	0.0
CUMBERLAND	90.1	3.2	0.9	1.1	0.0	0.0	0.0	0.0	0.0	4.2	0.4	0.0	0.1	0.0
DEKALB	90.8	1.7	2.7	3.4	0.0	0.0	0.0	0.0	0.6	0.2	0.0	0.0	0.7	0.0
DEWITT	90.1	0.0	9.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
DOUGLAS	81.0	6.3	9.4	1.5	0.0	0.0	0.0	0.0	0.0	1.8	0.0	0.0	0.0	0.0
DUPAGE	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
EDGAR	99.6	0.0	0.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
EDWARDS	92.6	0.1	1.3	1.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.1	2.5
EFFINGHAM	82.5	1.4	4.5	1.6	0.0	0.0	0.1	0.0	0.0	6.3	0.0	0.2	3.4	0.0
FAYETTE	98.5	0.0	0.5	0.4	0.0	0.0	0.0	0.0	0.0	0.4	0.0	0.0	0.2	0.0
FORD	85.5	1.1	0.0	11.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.0	0.0
FRANKLIN	98.5	0.0	0.5	1.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
FULTON	87.0	2.3	2.1	0.2	0.0	0.0	0.0	0.0	0.0	2.5	0.0	0.9	1.5	3.4
GALLATIN	88.3	0.0	4.9	0.7	0.0	0.0	0.0	0.0	0.0	6.0	0.0	0.0	0.0	0.0
GREENE	74.4	2.9	2.6	12.5	0.0	0.0	0.0	0.0	0.5	0.0	0.0	0.0	0.7	6.3
GRUNDY	100.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
HAMILTON	98.5	0.1	1.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0
HANCOCK	79.8	0.1	0.4	6.1	0.0	0.7	0.9	0.0	0.0	7.4	0.0	0.0	0.3	4.4
HARDIN	68.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	28.6	0.0	0.0	0.0	3.3
HENDERSON	75.7	0.4	3.6	0.0	0.0	0.0	15.3	0.0	0.1	3.7	1.1	0.2	0.0	0.0
HENRY	82.1	1.3	3.9	1.4	0.0	0.0	0.0	0.0	0.1	9.0	0.0	0.1	0.0	2.1
IROQUOIS	77.0	6.8	2.6	4.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	4.3	4.6

Appendix B. Continued.

County	Conservation Practice[a] 1	2	3	4	5	6	7	8	9	10	11	12	13	14
JACKSON	96.9	0.2	0.3	0.0	0.0	0.0	0.0	0.0	0.0	2.5	0.0	0.0	0.1	0.0
JASPER	84.9	0.0	6.1	6.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.9	0.0
JEFFERSON	94.3	0.6	0.9	0.0	0.0	0.0	0.0	0.0	0.0	3.6	0.1	0.0	0.4	0.1
JERSEY	90.0	0.1	0.4	4.2	0.0	0.0	0.0	0.0	0.0	3.6	0.0	0.0	0.0	1.7
JO DAVIES	49.5	1.5	3.2	0.8	0.0	0.0	0.2	0.2	0.1	43.5	0.1	0.2	0.4	0.5
JOHNSON	71.8	1.4	4.4	2.7	0.0	0.0	0.0	0.0	0.0	16.3	0.1	0.0	0.1	3.2
KANE	26.9	11.4	33.7	26.5	1.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
KANKAKEE	96.6	0.0	0.0	3.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
KENDALL	67.9	6.7	21.1	0.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.7	1.1
KNOX	73.8	0.5	3.1	2.8	0.0	0.0	0.0	0.0	0.0	18.6	0.0	0.0	0.3	0.8
LAKE	100.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
LASALLE	98.5	0.1	0.2	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.0
LAWRENCE	97.8	0.6	0.4	0.0	0.0	0.0	0.1	0.5	0.0	0.4	0.0	0.0	0.0	0.1
LEE	77.1	1.2	8.4	8.8	0.0	0.0	0.0	0.0	0.1	3.0	0.0	0.0	1.5	0.0
LIVINGSTON	98.6	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.2	0.1
LOGAN	88.4	0.0	2.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.8	7.6
MCDONOUGH	91.4	0.0	3.0	0.0	0.0	0.0	0.4	0.0	0.1	1.7	0.0	0.0	1.1	2.2
MCHENRY	77.8	8.2	7.0	4.9	0.0	0.0	0.0	0.0	1.8	0.0	0.0	0.0	0.3	0.0
MCLEAN	85.1	5.2	6.5	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.4	2.6
MACON	88.8	0.0	7.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3.1	0.4
MACOUPIN	98.4	0.2	0.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.4	0.3
MADISON	87.1	0.6	3.5	1.1	0.0	0.3	0.0	0.0	0.0	6.9	0.0	0.0	0.5	0.0
MARION	88.8	0.8	7.3	1.5	0.0	0.0	0.0	0.0	0.0	0.3	0.1	0.0	0.6	0.6
MARSHALL	77.1	1.6	12.7	4.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3.8	0.8
MASON	95.9	0.1	1.0	0.7	0.0	0.0	0.0	0.0	0.0	2.3	0.0	0.0	0.0	0.0
MASSAC	75.6	0.3	1.2	1.9	0.0	0.1	0.2	0.1	0.0	20.6	0.0	0.0	0.0	0.1
MENARD	90.2	3.9	4.3	0.0	0.0	0.0	0.2	0.3	0.0	1.0	0.0	0.0	0.0	0.0
MERCER	82.7	1.2	3.0	0.2	0.0	0.0	0.0	0.0	0.0	12.8	0.0	0.1	0.0	0.0
MONROE	62.9	18.3	8.4	5.1	0.0	0.0	0.0	0.0	2.8	0.1	0.0	0.6	0.2	1.6
MONTGOMERY	93.5	0.0	2.7	1.2	0.0	0.0	0.1	0.3	0.0	1.4	0.1	0.0	0.1	0.5
MORGAN	94.8	0.0	1.5	0.0	0.0	0.8	0.0	0.0	0.0	0.2	0.0	0.0	2.8	0.0
MOULTRIE	85.9	3.2	7.2	1.4	0.0	0.0	0.0	0.0	0.0	2.4	0.0	0.0	0.0	0.0
OGLE	74.6	2.3	2.7	19.1	0.0	0.0	0.0	0.0	0.0	1.1	0.0	0.0	0.1	0.0
PEORIA	92.8	1.2	0.7	0.0	0.0	1.4	0.3	1.1	0.0	2.1	0.4	0.0	0.0	0.0
PERRY	96.6	0.0	0.7	0.3	0.0	0.0	0.0	0.5	0.0	1.2	0.3	0.0	0.0	0.3
PIATT	83.3	0.0	10.7	1.3	0.0	0.0	0.0	0.0	0.0	2.7	0.0	0.1	1.7	0.1
PIKE	93.2	1.4	1.1	0.5	0.0	0.1	0.2	0.0	0.0	3.3	0.1	0.0	0.1	0.0
POPE	77.2	0.5	1.1	0.9	0.0	0.0	0.2	0.0	0.0	18.0	0.0	1.2	0.2	0.7
PULASKI	97.4	0.0	0.3	0.0	0.0	0.0	0.0	0.0	0.0	1.2	0.5	0.0	0.6	0.0

Appendix B. Continued.

County	Conservation Practice[a] 1	2	3	4	5	6	7	8	9	10	11	12	13	14
PUTNAM	100.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
RANDOLPH	85.7	3.4	1.5	2.7	0.0	0.0	0.0	0.0	0.0	3.6	0.0	0.2	0.5	2.3
RICHLAND	81.0	0.4	0.5	3.5	0.0	0.0	0.0	0.1	0.0	13.2	0.2	0.0	0.9	0.2
ROCK ISL.	84.3	2.8	2.6	3.7	0.0	0.0	0.0	0.0	0.0	6.5	0.0	0.0	0.0	0.0
ST. CLAIR	85.2	10.0	3.4	0.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.7
SALINE	90.9	0.0	3.2	0.0	0.0	0.0	0.1	0.2	0.0	1.4	0.2	0.0	0.2	3.8
SANGAMON	80.2	1.1	1.1	8.2	0.0	0.0	0.2	0.1	0.0	0.2	0.0	0.0	2.9	6.1
SCHUYLER	87.8	0.0	3.5	1.3	0.0	0.0	0.1	0.0	0.0	4.0	0.0	0.0	2.3	0.9
SCOTT	89.2	0.0	0.7	6.2	0.0	0.0	0.0	0.1	0.0	2.7	0.0	0.1	0.9	0.0
SHELBY	92.9	0.0	1.1	0.0	0.0	0.0	0.0	0.0	0.0	5.6	0.0	0.0	0.2	0.2
STARK	96.7	1.4	1.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.6	0.0
STEPHENSON	67.7	2.9	6.0	9.6	0.0	0.0	0.0	0.0	0.3	13.4	0.0	0.1	0.0	0.0
TAZEWELL	87.2	5.7	1.7	0.3	0.0	0.0	0.0	0.0	0.0	2.7	0.0	0.0	1.1	1.2
UNION	83.1	0.2	3.6	0.8	0.0	0.1	0.1	0.6	0.0	9.6	0.0	0.0	0.8	1.1
VERMILION	93.4	1.5	2.2	0.6	0.0	0.0	0.0	0.0	0.0	0.2	0.0	0.0	2.0	0.1
WABASH	84.4	5.8	2.7	0.0	0.0	0.0	0.2	0.0	0.0	0.5	0.0	0.0	0.0	6.4
WARREN	94.9	2.7	1.3	0.0	0.0	0.3	0.3	0.0	0.0	0.0	0.0	0.0	0.3	0.0
WASHINGTON	87.6	0.2	0.9	1.8	0.0	0.0	0.0	0.0	0.0	7.0	0.0	0.0	0.0	2.4
WAYNE	94.1	0.0	2.4	0.6	0.0	0.0	0.0	0.0	0.0	0.6	0.0	0.0	0.3	2.0
WHITE	86.4	4.5	4.0	0.0	0.0	0.0	0.0	0.0	0.0	2.8	0.0	0.0	0.0	2.3
WHITESIDE	81.4	2.1	3.6	9.0	0.0	0.0	0.0	0.0	0.4	0.6	0.0	0.0	1.2	1.6
WILL	51.2	10.7	25.4	12.2	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.0	0.3	0.0
WILLIAMSON	90.1	0.1	2.0	1.7	0.0	0.0	0.0	0.1	0.0	5.0	0.0	0.4	0.2	0.3
WINNEBAGO	68.2	2.6	7.3	10.8	0.0	0.0	0.0	0.0	0.0	10.6	0.4	0.0	0.2	0.0
WOODFORD	78.4	3.5	8.4	1.4	0.0	0.0	0.0	0.4	0.0	5.8	0.1	0.0	0.0	2.0

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[a]

CP1	Introduced (cool season) grasses and legumes.
CP2	Native (warm season) grasses.
CP3	Tree plantings.
CP4	Permanent wildlife habitat.
CP5	Field windbreaks.
CP6	Diversions.
CP7	Erosion control structures.
CP8	Grass waterways.
CP9	Shallow water areas for wildlife.
CP10	Already in grass.
CP11	Already in trees.
CP12	Wildlife food plots.
CP13	Vegetative filter strips.
CP14	Trees on wetlands.

Appendix C. Correlation coefficients between Illinois regional indices of bobwhite abundance, winter weather, and cycle phase.

		Snow[a]		Cycle[b]	
Region	Index	r	P	r	P
	KPT	-0.57	0.017	0.43	0.089
South	KPA	-0.30	0.236	0.56	0.020
	MBC	0.23	0.368	0.53	0.028
	KPT	-0.63	0.007	0.31	0.231
South-central	KPA	-0.57	0.016	0.54	0.025
	MBC	-0.72	0.001	0.09	0.719
	KPT	-0.63	0.006	0.11	0.682
West-central	KPA	-0.47	0.059	0.25	0.342
	MBC	-0.26	0.321	0.28	0.283
	KPT	-0.78	0.000	0.30	0.233
Statewide	KPA	-0.47	0.052	0.59	0.011
	MBC	-0.60	0.011	0.24	0.362

[a] Number of days of snow cover ≥ 2.54cm the previous winter.

[b] See text for explanation.

Appendix D. Summary table of multiple linear regression analysis of KPT using snow, cycle phase, and amount of CRP as predictors, Illinois, 1974-1991.

Dependent Variable: Annual bobwhite kill per unit effort (KPT)

N = 18
R Squared = 0.725
Adjusted R Squared = 0.666
Std. Error of Estimate = 0.141

Variable	Coefficient	Std. Error	T	P
Constant	0.786	0.403	1.951	0.071
Snow[a]	-0.008	0.002	-3.781	0.002
Cycle[b]	0.013	0.006	2.321	0.036
CRP[c]	0.007	0.005	1.920	0.076

Analysis of Variance

Source	Sum-of-Squares	DF	Mean Square	F-Ratio	P
Regression	0.729	3	0.243	12.302	0.000
Residual	0.277	14	0.020		
Total	1.006	17			

[a] Number of days of snow cover ≥ 2.54 cm the previous winter.

[b] See text for explanation.

[c] Hectares of CRP land (x 10000)

Appendix E. Summary table of multiple linear regression analysis of KPA using snow, cycle phase, and amount of CRP as predictors, Illinois, 1974-1991.

Dependent Variable: Annual bobwhite kill per unit area (KPA)

N = 18
R Squared = 0.514
Adjusted R Squared = 0.410
Std. Error of Estimate = 3.686

Variable	Coefficient	Std. Error	T	P
Constant	-5.764	10.566	-0.546	0.594
Snow[a]	-0.101	0.052	-1.935	0.074
Cycle[b]	0.374	0.144	2.588	0.022
CRP[c]	0.002	0.116	0.018	0.986

Analysis of Variance

Source	Sum-of-Squares	DF	Mean Square	F-Ratio	P
Regression	201.50	3	67.165	4.942	0.0152
Residual	190.27	14	13.590		
Total	391.77	16			

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[a] Number of days of snow cover ≥ 2.54 cm the previous winter.

[b] See text for explanation.

[c] Hectares of CRP land (x 10000)

Appendix F. Summary table of multiple linear regression analysis of MBC using snow, cycle phase, and amount of CRP as predictors, Illinois, 1975-1991.

Dependent Variable: Mean annual male bobwhite call count (MBC)

N = 17
R Squared = 0.658
Adjusted R Squared = 0.579
Std. Error of Estimate = 1.761

Variable	Coefficient	Std. Error	T	P
Constant	0.865	4.607	0.188	0.854
Snow[a]	-0.066	0.024	-2.767	0.016
Cycle[b]	0.195	0.066	2.941	0.012
CRP[c]	0.141	0.054	2.596	0.022

Analysis of Variance

Source	Sum-of-Squares	DF	Mean Square	F-Ratio	P
Regression	77.59	3	25.86	8.340	0.002
Residual	40.31	13	3.10		
Total	117.90	16			

[a] Number of days of snow cover ≥ 2.54 cm the previous winter.

[b] See text for explanation.

[c] Hectares of CRP land (x 10000)

Appendix G. Summary table of ANOVA of KPT, KPA, and MBC across all regions, Illinois, 1985-1991.

Dependent Variable	Source	Sum-of-Squares	DF	Mean Square	F-Ratio	P
KPT	Group[a]	0.48	2	0.24	0.37	0.688
	County	72.49	47	1.54	2.39	0.000
	Year	8.48	6	1.41	2.19	0.044
	Group x Year	6.45	12	0.54	0.83	0.617
	Group x Year[b]	1.09	1	1.09	1.69	0.195

Dependent Variable	Source	Sum-of-Squares	DF	Mean Square	F-Ratio	P
KPA	Group[a]	1069.84	2	534.93	1.00	0.369
	County	82765.48	47	1760.97	3.30	0.000
	Year	3121.46	6	520.24	0.97	0.443
	Group x Year	5785.24	12	482.10	0.90	0.545
	Group x Year[b]	2892.12	1	2892.12	5.41	0.021

Dependent Variable	Source	Sum-of-Squares	DF	Mean Square	F-Ratio	P
MBC	Group[a]	297.32	2	148.66	5.89	0.003
	County	11817.36	47	288.23	11.42	0.000
	Year	869.28	6	144.88	5.74	0.000
	Group x Year	338.59	12	28.22	1.12	0.346
	Group x Year[b]	38.61	1	38.61	1.53	0.217

[a] HIGH, MID, LOW county groups (see text for explanation).

[b] Linear trend.

Appendix H. Summary table of multiple linear regression analysis of KPT using snow, cycle phase, and amount of CRP as predictors, South Region, Illinois, 1975-1991.

Dependent Variable: Annual bobwhite kill per unit effort (KPT)

N = 17
R Squared = 0.499
Adjusted R Squared = 0.383
Std. Error of Estimate = 0.297

Variable	Coefficient	Std. Error	T	P
Constant	0.448	0.841	0.533	0.603
Snow[a]	-0.011	0.005	-2.259	0.042
Cycle[b]	0.025	0.012	2.081	0.058
CRP[c]	0.030	0.057	0.549	0.592

Analysis of Variance

Source	Sum-of-Squares	DF	Mean Square	F-Ratio	P
Regression	1.144	3	0.381	4.315	0.026
Residual	1.149	13	0.088		
Total	2.293	16			

[a] Number of days of snow cover ≥ 2.54 cm the previous winter.

[b] See text for explanation.

[c] Hectares of CRP land (x 10000)

Appendix I. Summary table of multiple linear regression analysis of KPA using snow, cycle phase, and amount of CRP as predictors, South Region, Illinois, 1975-1991.

Dependent Variable: Annual bobwhite kill per unit area (KPA)

N = 17
R Squared = 0.426
Adjusted R Squared = 0.294
Std. Error of Estimate = 6.416

Variable	Coefficient	Std. Error	T	P
Constant	-9.155	18.144	-0.505	0.622
Snow[a]	-0.167	0.105	-1.595	0.135
Cycle[b]	0.498	0.256	1.944	0.074
CRP[c]	-1.114	1.260	-0.886	0.392

Analysis of Variance

Source	Sum-of-Squares	DF	Mean Square	F-Ratio	P
Regression	397.56	3	132.52	3.220	0.058
Residual	535.05	13	41.16		
Total	932.61	16			

[a] Number of days of snow cover ≥ 2.54 cm the previous winter.

[b] See text for explanation.

[c] Hectares of CRP land (x 10000)

Appendix J. Summary table of multiple linear regression analysis of MBC using cycle phase and amount of CRP as predictors, South Region, Illinois, 1975-1991.

Dependent Variable: Mean annual male bobwhite call count (MBC)

N = 17
R Squared = 0.364
Adjusted R Squared = 0.273
Std. Error of Estimate = 4.271

Variable	Coefficient	Std. Error	T	P
Constant	-3.950	10.865	-0.364	0.722
Cycle[a]	0.288	0.158	1.820	0.090
CRP[b]	-0.988	0.741	-1.335	0.203

Analysis of Variance

Source	Sum-of-Squares	DF	Mean Square	F-Ratio	P
Regression	146.07	2	73.03	4.003	0.042
Residual	255.40	14	18.24		
Total	401.47	16			

[a] See text for explanation.

[b] Hectares of CRP land (x 10000)

Appendix K. Summary table of ANOVA of KPT, KPA, and MBC in South region, Illinois, 1985-1991.

Dependent Variable	Source	Sum-of-Squares	DF	Mean Square	F-Ratio	P
	Group[a]	13.03	1	13.03	11.66	0.001
	County	6.56	9	0.73	0.65	0.747
KPT	Year	5.90	6	0.98	0.88	0.516
	Group x Year	7.50	6	1.25	1.12	0.364
	Group x Year[b]	2.65	1	2.65	2.37	0.129

Dependent Variable	Source	Sum-of-Squares	DF	Mean Square	F-Ratio	P
	Group[a]	109.75	1	109.75	0.23	0.634
	County	5774.26	9	641.58	1.34	0.239
KPA	Year	1102.38	6	183.73	0.38	0.886
	Group x Year	1901.23	6	316.87	0.66	0.681
	Group x Year[b]	60.37	1	60.37	0.13	0.724

Dependent Variable	Source	Sum-of-Squares	DF	Mean Square	F-Ratio	P
	Group[a]	156.45	1	156.45	6.47	0.015
	County	784.30	6	130.71	5.41	0.001
MBC	Year	588.20	6	98.03	4.06	0.003
	Group x Year	110.04	6	18.34	0.76	0.607
	Group x Year[b]	45.81	1	45.81	1.90	0.177

[a] ABOVE AND BELOW county groups (see text for explanation).

[b] Linear trend.

Appendix L. Summary table of multiple linear regression analysis of KPT using snow, cycle phase, and amount of CRP as predictors, Southcentral Region, Illinois, 1975-1991.

Dependent Variable: Annual bobwhite kill per unit effort (KPT)

N = 17
R Squared = 0.571
Adjusted R Squared = 0.472
Std. Error of Estimate = 0.205

Variable	Coefficient	Std. Error	T	P
Constant	0.931	0.571	1.628	0.127
Snow[a]	-0.007	0.003	-2.601	0.022
Cycle[b]	0.016	0.008	1.943	0.074
CRP[c]	0.032	0.015	1.917	0.078

Analysis of Variance

Source	Sum-of-Squares	DF	Mean Square	F-Ratio	P
Regression	0.722	3	0.241	5.763	0.010
Residual	0.543	13	0.042		
Total	1.265	16			

[a] Number of days of snow cover ≥ 2.54 cm the previous winter.

[b] See text for explanation.

[c] Hectares of CRP land (x 10000)

Appendix M. Summary table of multiple linear regression analysis of KPA using snow, cycle phase, and amount of CRP as predictors, Southcentral Region, Illinois, 1975-1991.

Dependent Variable: Annual bobwhite kill per unit area (KPA)

N = 17
R Squared = 0.554
Adjusted R Squared = 0.451
Std. Error of Estimate =

Variable	Coefficient	Std. Error	T	P
Constant	1.828	17.370	0.105	0.918
Snow[a]	-0.230	0.087	-2.643	0.020
Cycle[b]	0.571	0.246	2.325	0.037
CRP[c]	-0.012	0.519	-0.027	0.979

Analysis of Variance

Source	Sum-of-Squares	DF	Mean Square	F-Ratio	P
Regression	622.47	3	207.49	5.376	0.013
Residual	501.76	13	38.60		
Total	1124.23	16			

[a] Number of days of snow cover ≥ 2.54 cm the previous winter.

[b] See text for explanation.

[c] Hectares of CRP land (x 10000)

Appendix N. Summary table of multiple linear regression analysis of MBC using snow and amount of CRP as predictors, Southcentral Region, Illinois, 1975-1991.

Dependent Variable: Mean annual male bobwhite call count (MBC)

N = 17
R Squared = 0.597
Adjusted R Squared = 0.539
Std. Error of Estimate = 2.546

Variable	Coefficient	Std. Error	T	P
Constant	16.843	1.202	14.018	0.000
Snow[a]	-0.130	0.035	-3.761	0.002
CRP[b]	0.329	0.193	1.695	0.112

Analysis of Variance

Source	Sum-of-Squares	DF	Mean Square	F-Ratio	P
Regression	134.24	2	67.12	10.365	0.002
Residual	90.66	14	6.48		
Total	224.90	16			

[a] Number of days of snow cover ≥ 2.54 cm the previous winter.

[b] Hectares of CRP land (x 10000)

Appendix O. Summary table of ANOVA of KPT, KPA, and MBC in Southcentral region, Illinois, 1985-1991.

Dependent Variable	Source	Sum-of-Squares	DF	Mean Square	F-Ratio	P
KPT	Group[a]	0.17	1	0.17	0.28	0.599
	County	27.26	21	1.30	2.17	0.005
	Year	3.82	6	0.64	1.06	0.389
	Group x Year	3.75	6	0.63	1.04	0.402
	Group x Year[b]	0.17	1	0.17	0.29	0.591

Dependent Variable	Source	Sum-of-Squares	DF	Mean Square	F-Ratio	P
KPA	Group[a]	5008.68	1	5008.68	7.02	0.009
	County	36546.20	21	1740.30	2.44	0.001
	Year	4994.37	6	832.39	1.17	0.328
	Group x Year	11913.19	6	1985.53	2.78	0.014
	Group x Year[b]	7537.23	1	7537.23	10.57	0.002

Dependent Variable	Source	Sum-of-Squares	DF	Mean Square	F-Ratio	P
MBC	Group[a]	56.70	1	56.70	2.21	0.140
	County	5611.83	22	255.08	9.94	0.000
	Year	891.93	6	148.65	5.79	0.000
	Group x Year	88.64	6	14.77	0.58	0.749
	Group x Year[b]	8.78	1	8.78	0.34	0.560

[a] ABOVE AND BELOW county groups (see text for explanation).

[b] Linear trend.

Appendix P. Summary table of multiple linear regression analysis of KPT using snow and amount of CRP as predictors, Westcentral Region, Illinois, 1975-1991.

Dependent Variable: Annual bobwhite kill per unit effort (KPT)

N = 17
R Squared = 0.456
Adjusted R Squared = 0.378
Std. Error of Estimate =

Variable	Coefficient	Std. Error	T	P
Constant	1.918	0.182	10.567	0.000
Snow[a]	-0.010	0.004	-2.726	0.016
CRP[b]	0.042	0.037	1.170	0.261

Analysis of Variance

Source	Sum-of-Squares	DF	Mean Square	F-Ratio	P
Regression	1.026	2	0.513	5.870	0.014
Residual	1.224	14	0.087		
Total	2.250	16			

[a] Number of days of snow cover ≥ 2.54 cm the previous winter.

[b] Hectares of CRP land (x 10000)

Appendix Q. Summary table of multiple linear regression analysis of KPA using snow, cycle phase, and amount of CRP as predictors, Westcentral Region, Illinois, 1975-1991.

Dependent Variable: Annual bobwhite kill per unit area (KPA)

N = 17
R Squared = 0.308
Adjusted R Squared = 0.148
Std. Error of Estimate = 8.218

Variable	Coefficient	Std. Error	T	P
Constant	0.948	23.917	0.040	0.969
Snow[a]	-0.149	0.106	-1.397	0.186
Cycle[b]	0.387	0.328	1.178	0.260
CRP[c]	1.134	1.127	1.005	0.333

Analysis of Variance

Source	Sum-of-Squares	DF	Mean Square	F-Ratio	P
Regression	389.96	3	129.99	1.925	0.175
Residual	877.83	13	67.53		
Total	1267.79	16			

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[a] Number of days of snow cover ≥ 2.54 cm the previous winter.

[b] See text for explanation.

[c] Hectares of CRP land (x 10000)

Appendix R. Summary table of multiple linear regression analysis of MBC using snow, cycle phase, and amount of CRP as predictors, Westcentral Region, Illinois, 1975-1991.

Dependent Variable: Mean annual male bobwhite call count (MBC)

N = 17
R Squared = 0.513
Adjusted R Squared = 0.401
Std. Error of Estimate = 3.329

Variable	Coefficient	Std. Error	T	P
Constant	-10.016	8.750	-1.145	0.273
Snow[a]	-0.026	0.042	-0.627	0.541
Cycle[b]	0.331	0.125	2.654	0.020
CRP[c]	-1.364	0.445	3.061	0.009

Analysis of Variance

Source	Sum-of-Squares	DF	Mean Square	F-Ratio	P
Regression	151.95	3	50.65	4.569	0.021
Residual	144.10	13	11.08		
Total	296.05	16			

[a] Number of days of snow cover ≥ 2.54 cm the previous winter.

[b] See text for explanation.

[c] Hectares of CRP land (x 10000)

Appendix S. Summary table of ANOVA of KPT, KPA, and MBC in Westcentral region, Illinois, 1985-1991.

Dependent Variable	Source	Sum-of-Squares	DF	Mean Square	F-Ratio	P
	Group[a]	0.00	1	0.00	0.01	0.943
	County	15.91	14	1.14	2.96	0.001
KPT	Year	5.59	6	0.93	2.42	0.033
	Group x Year	2.11	6	0.35	0.91	0.489
	Group x Year[b]	0.09	1	0.09	0.23	0.631

Dependent Variable	Source	Sum-of-Squares	DF	Mean Square	F-Ratio	P
	Group[a]	523.92	1	523.92	2.33	0.131
	County	20119.82	14	1437.13	6.39	0.000
KPA	Year	3547.64	6	591.27	2.63	0.022
	Group x Year	1483.45	6	247.24	1.10	0.369
	Group x Year[b]	9.12	1	9.12	0.04	0.841

Dependent Variable	Source	Sum-of-Squares	DF	Mean Square	F-Ratio	P
	Group[a]	914.10	1	914.10	77.05	0.000
	County	2795.59	10	279.56	23.56	0.000
MBC	Year	455.77	6	75.96	6.40	0.000
	Group x Year	313.26	6	52.21	4.40	0.001
	Group x Year[b]	206.33	1	206.33	17.39	0.000

[a] ABOVE AND BELOW county groups (see text for explanation).

[b] Linear trend.

SIMULATED EFFECTS OF CONSERVATION RESERVE PROGRAM FIELDS ON LOCAL BOBWHITE HABITAT

John L. Roseberry, Bryan J. Richards, and Thomas P. Hollenhorst, Cooperative Wildlife Research Laboratory, Southern Illinois University-Carbondale

INTRODUCTION

Wildlife officials are becoming increasingly concerned about the widespread decline in abundance of northern bobwhite (Colinus virginianus) in the United States. Over the past 3 decades, populations of this important gamebird have decreased significantly in at least 24 of the 31 states comprising its primary range (Brennan 1991). In Illinois, annual hunter harvests of bobwhites are currently < 40% of those recorded in the late 1950's (Anderson and Campbell 1991, Preno and Labisky 1971). Intensified land use, especially agricultural, is commonly blamed for this trend. In particular, monocultural cropping patterns, removal of brushing fencerows and woody hedgerows to accommodate larger fields, and reduced amounts of grassy/herbaceous vegetation are thought to be primarily responsible for widespread loss and deterioration of habitat for bobwhite and other upland species (Kenney 1985).

The Conservation Reserve Program (CRP) was a provision of the 1985 Food Securities Act (Farm Bill) that encouraged landowners to retire potentially erodible cropland for a minimum of 10 years. Several optional cover types (Conservation Practices or CPs) were available including various grass/legume mixtures, shrubs, and trees. Positive benefits to wildlife were widely anticipated, especially where nesting and brood/rearing

cover were generally lacking (Isaacs and Howell 1988, Schenck and Williamson 1991). It was recognized, however, that such benefits would depend on a number of factors including characteristics of the CRP vegetation and the spatial relationship of CRP fields with other habitat components (Langer 1989, Burger et al. 1990, Stauffer et al. 1990)

Our objective was to assess the potential contribution of CRP to bobwhite habitat in a selected county of Illinois using simulation and modeling in combination with knowledge of the actual composition and spatial distribution of land-use types including CRP fields. We used remote sensing and ground referencing to classify land-use conditions in Hamilton County, southcentral Illinois. Spatial relationships of CRP fields to other habitat components and soil types were investigated using Geographic Information System (GIS) computer software. We employed habitat modeling and simulation to evaluate the potential contribution of CRP to bobwhite habitat under various scenarios relating to composition and management of CRP and cropfields.

STUDY AREA

Hamilton County occupies 112,700 ha in southeastern Illinois (Fig. 1). Topography varies from gently rolling Pennsylvanian-age bedrock formations to large areas of nearly level soils formed from Illinoisan glacial till and lake-bed sediments. Upland soil associations are Bluford-Ava, Grantsburg-Zanesville, and Bluford-Hoyleton-Cisne. Floodplain and glacial lake bed soil associations are Belknap-Bonnie, and Zipp (Currie 1986).

Agriculture dominates the land use with approximately 46% of the county in intertilled cropland (corn and soybeans), 13% in grasslands (pasture, hay, CRP), and 8% in winter wheat. Forests occupy approximately 16% of the land area and brushy oldfields approximately 3%.

METHODS

Land use on approximately 30% of the county was determined by ground surveys August-September 1989 and mapped on acetate overlays of high altitude color infrared photographs (4 April 1988; scale 1:21,120). A Landsat V Thematic Mapper (TM) image (17 June 1989) of a portion of southern Illinois including Hamilton County was purchased from EOSAT Corporation, Lanham, MD. The georeferenced quarter scene was reduced dimensionally from 6 spectral bands to a single channel digital array representing 228 spectral classes by Ducks Unlimited Habitat Inventory and Evaluation Program, Long Grove, IL, using unsupervised principal components and maximum likelihood classification techniques. Subsequent classification of the Landsat scene was conducted at the Cooperative Wildlife Research Laboratory, Southern Illinois University -Carbondale, using a Hewlett Packard Vectra RS/25C computer, a 19" Mitsubishi 1024 X 760 resolution graphics monitor, and a PC version of Earth Resources Laboratory Applications Software (ELAS) (Graham et al. 1985) modified by Ducks Unlimited (Koeln et al. 1986).

Digital spectral classes within known cover types were grouped into land-use categories (training classes). These training classes, along with ground reference data and direct

interpretation of CIR aerial photography were then used to manually edit (digitize) the scene into the following categories: intertilled cropland, grass/legume, deciduous forest, coniferous forest, small grain, oldfield, water, developed (urban areas and major roads), hedgerow, drainage, barren, and farmsteads. CRP fields were added separately to the classified image as it was not possible to distinguish this land-use type from other grasslands using the multispectral satellite image. Location of all CRP land in the county was obtained from maps on file with the Hamilton County Agricultural Stabilization and Conservation Service (ASCS) office and transferred to acetate overlays of the color infrared photographs. Individual CRP fields were then identified on a graphic display of the classified satellite image and the corresponding digital data file changed to the CRP category using a RASTER EDITING procedure of Map and Image Processing System (MIPS) software (Miller et al. 1989)) running on an IBM Model 80 computer with a 16" 1020 X 1280 resolution Sony graphics monitor.

The final digitized dataset was a 1.44 MB file with land use in each 0.09 ha (30 x 30 m) parcel of the County represented by an alphanumeric character. The column-row designation of the northwest corner of each political section in the county was stored in another data file along with the corresponding township, range, and section number.

We evaluated the potential contribution of CRP to bobwhite habitat with the aid of an existing habitat model (Roseberry and Richards 1992) designed to grossly assess bobwhite habitat

suitability on a landscape or larger scale based on amount and spatial distribution of land cover types discernable from remote sensing. The model was modified to systematically access 108 x 108 matrices of digital values representing land use conditions (at 0.09-ha resolution) of each 2.59 sq km section in the county plus a 0.8-km buffer strip. The model produced a quantitative index of bobwhite habitat suitability for each section based on amount (relative to an assumed optimum), quality, and interspersion/juxtaposition of various land-use types and their assumed contribution to the life requisites of food, cover, and nesting.

Simulations were run in 2 modes: with CRP fields extant and with CRP fields reverted to their original status as cropland. Various sets of conditions reflecting composition, structure, and management of CRP fields and type and overwinter management of croplands were simulated by altering the value of coefficients representing "quality" or suitability of CRP and cropland as bobwhite habitat from 0.1 (minimum) to 1.0 (optimum). Runs representing various combinations of conditions were made with and without CRP and the resulting indices of habitat suitability (HSI) compared on a section by section basis.

A general soils map of Hamilton County (Currie 1986) was scanned into a digital color raster at 200 dpi. Individual soil types were then converted to vector polygons using MIPS software and overlaid on the classified land cover raster file to determine the frequency of CRP pixels in each soil type. Various other attributes of CRP fields relating to size and spatial

relationship with other land-use types were determined using modules in the habitat model and the MIPS software.

RESULTS

Characteristics of CRP Fields

Approximately 10,163 ha (9.0%) of Hamilton County were enrolled in the CRP during the first 9 signup periods (March 1986 - August 1989). The county ranked 1st and 3rd in the State in terms of relative and total amounts of CRP. Almost all (98.5%) of the enrolled land was committed to CP-1 (introduced grasses and legumes). Statewide, 86.9% of CRP land was in CP-1.

Two-hundred ninety two (67.6%) of Hamilton County's 432 political sections contained CRP land; 110 (25.5%) had from 1 to 16 ha, 63 (14.6%) from 17-32 ha, 74 (17.1%) from 33-65 ha, and 45 (10.4%) over 65 ha. Except for the very flat, intensively cultivated portions of northeastern and southeastern Hamilton County, spatial distribution of CRP fields was fairly uniform (Fig. 2). In general, sections with no CRP tended to be more intensively cultivated and less forested than did those with CRP. Sections with > 16 ha of CRP averaged 20% woods, 56% cropland, and 15% grasslands prior to initiation of the program. In contrast, sections with no CRP were 76% cultivated, 10% woods and 9% grassland.

The relationship of CRP fields to particular soil types was mainly a function of terrain. Approximately 78% of all CRP acreage represented Bluford-Ava soils which make up about 44% of the county and are found primarily on undulating to rolling loess-covered till plains. Most of the remaining CRP land (17%)

was on Grantsburg-Zanesville soils which occupy 20% of the county and likewise are often sloping. Both the Bluford-Ava and Grantsburg-Zanesville soils associations are rated "good" in terms of potential for producing grasses and legumes (Currie 1986). Soils characteristic of level floodplains and glacial lake beds (Belknap-Bonnie and Zipp) supported little or no CRP as would be expected.

Size of individual CRP fields ranged from < 1 to > 80 ha (median = 7.9 ha). This was similar to the size of cropfields not enrolled in the program (median = 8.2 ha). CRP fields, however, tended to be located in closer proximity to protective cover than did remaining cropfields. Almost 44% of all CRP land was within 90 m of a woods or a woody hedgerow compared to only 31% for remaining cropland. In contrast, 45% of remaining cropland was more > 240 m from protective cover compared to 33% for CRP land.

As the preceding would suggest, CRP land tended to be situated in better bobwhite habitat than did land not enrolled or not eligible for the program. Over 70% of the sections with no CRP were judged poor to fair bobwhite habitat while only 13% were rated good to excellent (Fig. 3). In contrast, 46% of the sections with > 16 ha of CRP had previously been excellent quail habitat whereas only 19% had been poor to fair.

Simulation Results

The ratio of sections in which bobwhite habitat suitability increased or declined with the addition of CRP land varied with

quality and amount of CRP and quality of replaced and remaining cropland (Table 1). When suitability of CRP land for bobwhite was assumed to be good, overall habitat conditions were improved in 56-70% of the sections and reduced in only 1-7% depending on quality of replaced and remaining cropland. When CRP suitability was assumed average, bobwhite habitat improved in 37-52% of the sections and declined in 3-15%, again depending on the cropland quality coefficient. Poor quality CRP improved bobwhite habitat in 12-19% of the sections while reducing it in 10-26%.

When CRP vegetation was assumed to be primarily grass or a grass/legume mix, its addition generally lowered the model's food component value; the exception being when average-good quality CRP replaced poor quality cropland. In most cases, however, the slight reduction in food value was more than compensated by a large increase in nesting value. When CRP fields were assumed to represent early oldfields rather than grassland, both the food and nesting component often increased and overall habitat quality was improved in 91% of the sections.

A run was also made in which all CRP land was converted to forest. The model suggested that this would improve the bobwhite HSI in 24% of the sections and reduce it in 44%. Only in those sections where CRP comprised < 16 ha was there a slight positive effect (31% improved:19% reduced).

DISCUSSION

Our study combined habitat modeling and simulation with knowledge of actual land use composition (including CRP fields)

and spatial patterns in Hamilton County, Illinois. As with any modeling exercise, results and conclusions were largely shaped by (though not necessarily apparent from) the logic, assumptions, and presumed functional relationships inherent in the model. For this reason, it was not surprising that certain prior conceptions of CRP potential to enhance bobwhite habitat were corroborated. Namely that it would depend on a) the amount of CRP land present, b) its suitability for bobwhite use, c) the suitability of replaced and remaining cropland for bobwhite use, d) the juxtaposition of CRP fields with other habitat components, and e) the composition and quality of existing bobwhite habitat, in particular the limiting factors (Fig. 4).

The simulated effect of low-quality CRP on bobwhite habitat was slightly to moderately negative, and intensified as the amount of CRP land increased. When CRP quality was good, bobwhite habitat was positively affected regardless of quality of replaced or remaining cropland and the positive effect increased as amount of CRP land increased. Average-quality CRP produced only minor positive effects for sections with < 6% CRP. Beneficial effects increased as amount of CRP increased and occurred regardless of the quality of replaced or remaining cropland.

Our model represented quality or suitability of CRP fields for bobwhite as a single coefficient value (range 0.1 - 1.0), an obvious oversimplification. In reality, the potential of CRP fields to meet various seasonal needs of bobwhite would depend on such things as composition and structure of growing and residual

vegetation which in turn would vary with type, rate, and success of initial plantings, site conditions, and years since establishment (age of field). Burger et al. (1990) found that newly established fields (< 3 years old) in northern Missouri were generally characterized by more bare ground and a larger annual weed component than older fields, thus making them more suitable as summer brood rearing and winter roosting habitat. As fields matured (> 3 years old), they become more rank and the grass component increased, thereby improving their value as nesting cover. These authors also considered CP-2 (warm-season grasses) and CP-4 (wildlife habitat) fields to be superior to CP-1 (cool-season grasses/legume) fields for bobwhite nesting and possibly brood rearing habitat. As noted earlier, almost all Illinois land (>98%) enrolled in CRP during the 1st 9 signups was placed in CP-1.

The timing and intensity of disturbance (e.g., mowing, grazing, burning, herbicide applications) can also influence suitability of CRP fields for bobwhite. Burger et al. (1990:82) noted that in northern Missouri ". . . disturbance [mowing] is a major factor limiting habitat quality on CRP lands . . . ." Except for the allowance of emergency haying during the drought year of 1988, mowing of CRP fields is technically permitted only for "weed control" and as part of the initial establishment of permanent cover (Hays et al. 1989). Annual mowing is not required by law; nevertheless, it appears to be a common practice in many areas. CRP monitoring in the Midwest and Southeast revealed some type of disturbance on > 40% of fields (Burger et al. 1990, Hays

unpubl. data). Much of this disturbance was from mowing, most of which occurred in late summer or autumn.

Most of our simulations were based on the premise that CRP vegetation consisted primarily of grasses, or grass/legume mixes. However, CRP fields in the Midwest (especially young fields) often contain a considerable annual weed component (Hays et al. 1989, Burger et al. 1990). In addition to age, the amount and composition of "weedy" vegetation in CRP fields would depend on such factors as relative success of initial plantings, season of initial tillage, and the proximity and composition of seed banks. Quail biologists have long recognized the importance of early successional vegetation to bobwhite (Stoddard 1931, Rosene 1969, Roseberry and Klimstra 1984). Such areas provide important year-round food sources as well as roosting sites and brood-rearing cover. Indeed, in our simulations, conversion of retired cropland to early oldfields improved bobwhite habitat in almost every instance. However, no CP specifically provides this type of cover, and accepted management practices often discourage the establishment of such vegetation. Burger et al. (1990) recommended that 1/3 of each CRP field be disced on a 3-year rotation as a means of maintaining early successional vegetation and increasing field-level diversity.

Langer (1989) noted that the juxtaposition of CRP fields to other land use types was a major determinant to their potential value as wildlife habitat. Our study supported this contention. Under most sets of simulated conditions, both positive and negative impacts of CRP were indicated at the sectional level.

This dichotomy reflected the fact that habitat conditions varied spatially and that CRP contributed positively to previously limiting components or life requisites in some sections while detracting from them in others.

In Hamilton County, CRP fields tended to be located in closer proximity to protective cover (woods, hedgerows) than did cropfields not enrolled in the program. This spatial relationship would be most beneficial for CRP fields that provided food. Immediate proximity to heavy cover would not be as critical if only nesting and/or brood rearing habitat were provided (Roseberry and Klimstra 1984). In areas lacking sufficient cover, a shrub component in CRP fields would increase their contribution to bobwhite habitat. Hays et al. (1989) noted that shrub cover was almost completely absent from most recently established CRP fields, but would likely increase with age unless suppressed by mowing or herbicide applications. The simulated conversion of all CRP acreage in Hamilton County to protective cover (forest) had an overall negative impact on bobwhite habitat (24% sections improved:44% reduced). A net advantage (31% improved:19% reduced) was realized only in sections containing relatively little CRP acreage (< 16 ha). However, more positive benefits might be expected in regions with less forested land than Hamilton County, Illinois.

RECOMMENDATIONS

The CRP offered considerable potential for enhancing northern bobwhite habitat (Burger et al. 1990), but this potential has not been fully realized (Brennan 1991). In fact,

local effects may have even been negative in situations where a) the composition and/or structure of CRP vegetation was unsuitable for bobwhite, b) untimely disturbance resulted in large nest or brood mortality, or c) life requisites contributed by CRP were not limiting, but replaced ones that were.

Warner and Etter (1985) suggested that wildlife habitat initiatives on agricultural lands should be addressed at 3 spatial scales - field (site), farm (landscape), and regional. This is certainly true of the CRP or similar land retirement programs if positive benefits to wildlife are to be maximized. Initially, regional conditions must be appraised before decisions are made to promote individual species or groups of species. Next, attention should be directed toward the spatial relationship of existing and proposed CRP fields to other habitat components (farm/landscape considerations), and a careful evaluation made of existing habitat conditions, especially those components or life requisites that appear to be limiting. Only with this knowledge can intelligent recommendations be made regarding which Conservation Practice would be most beneficial to a particular species. Finally, efforts must be directed toward promoting the establishment and maintenance of favorable vegetative composition and structure on retired acres (field/site considerations). The latter will necessitate action at both the national level where contract provisions are established (Cook 1989), and the local level where individual land owners are advised and directed (Miller and Bromley 1989).

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Table 1. Percentage of sections in which bobwhite habitat quality increased:decreased with addition of CRP Land, Hamilton County, Illinois.

Quality of CRP Cropland[a]		CRP Land Per Section (ha)				
		1-16	17-32	33-65	>65	Total
good	good	36:3	68:3	66:10	73.13	56:7
good	fair	39:2	70:6	76:7	80:9	61:5
good	poor	39:1	84:0	91:30	93:2	70:1
fair	good	16:6	49:16	51:26	47:22	37:15
fair	fair	18:3	56:8	60:12	56:20	42:9
fair	poor	17:2	60:6	74:4	84:2	52:3
poor	good	4:7	14:19	23:38	11:64	12:26
poor	fair	5:7	16:19	30:35	16:51	16:24
poor	poor	3:4	19:8	35:12	33:24	19:10

[a] Replaced and remaining.

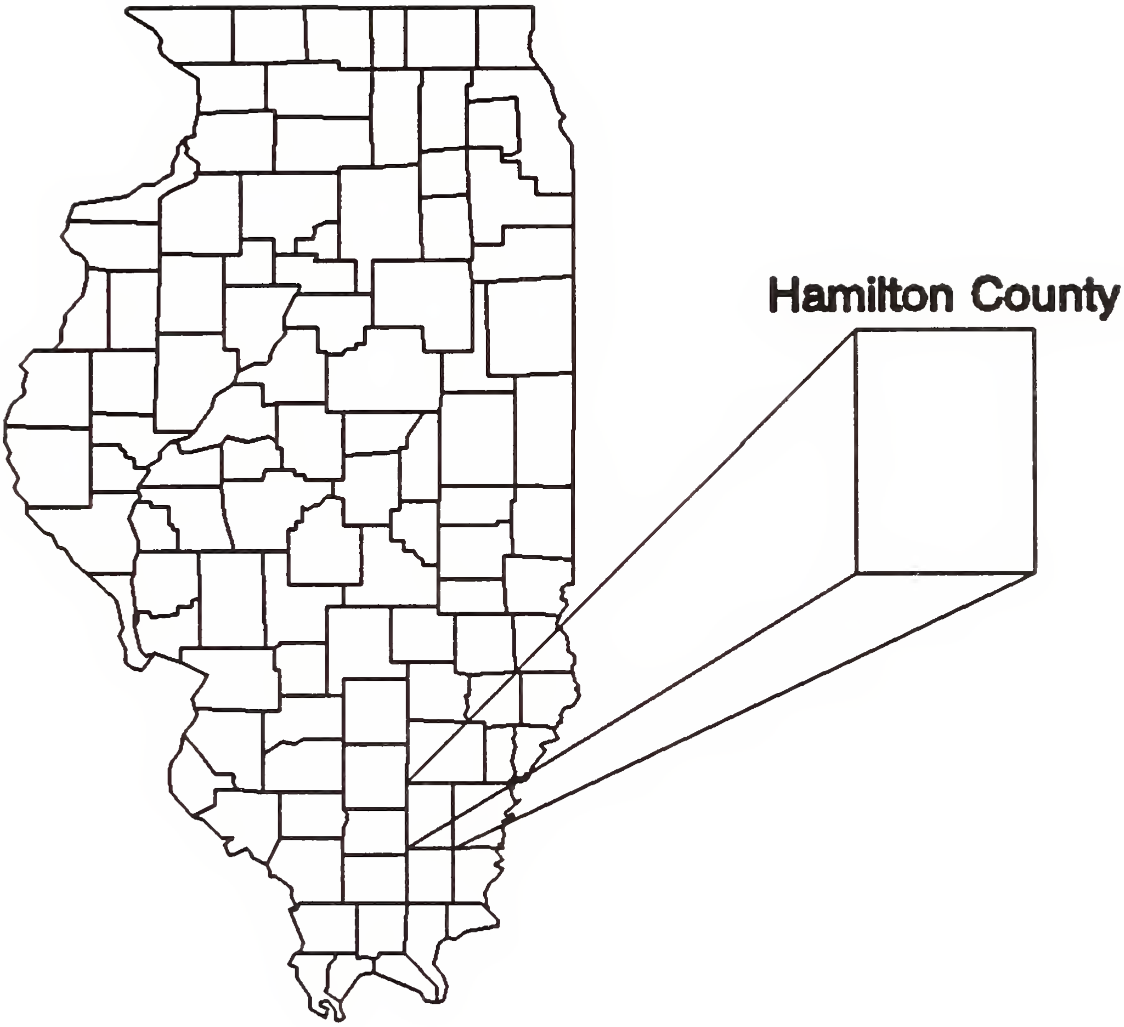

Figure 1. Location of Hamilton County, Illinois.

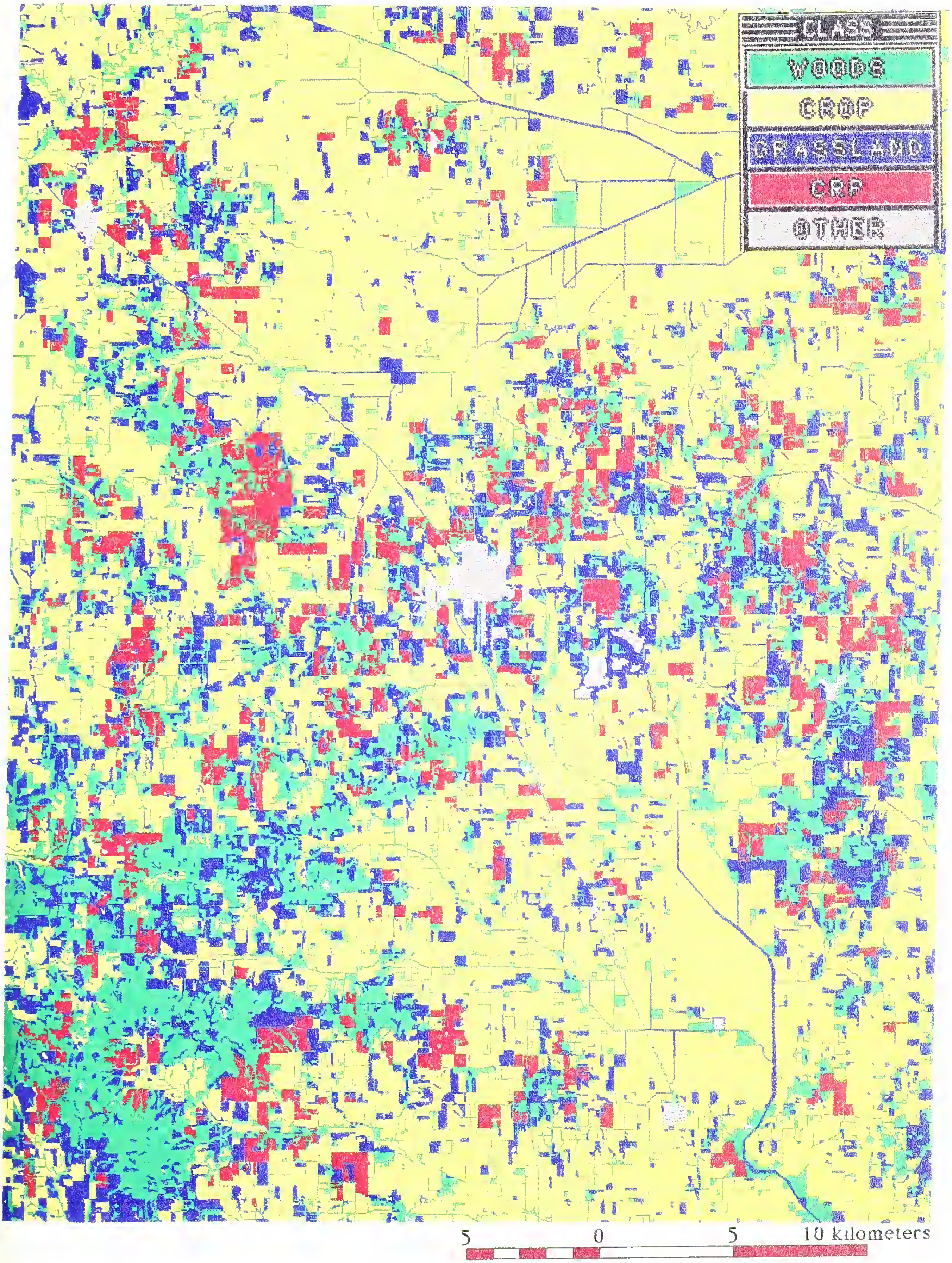

Figure 2. CRP fields and other land use types, Hamilton County, Illinois, 1989.

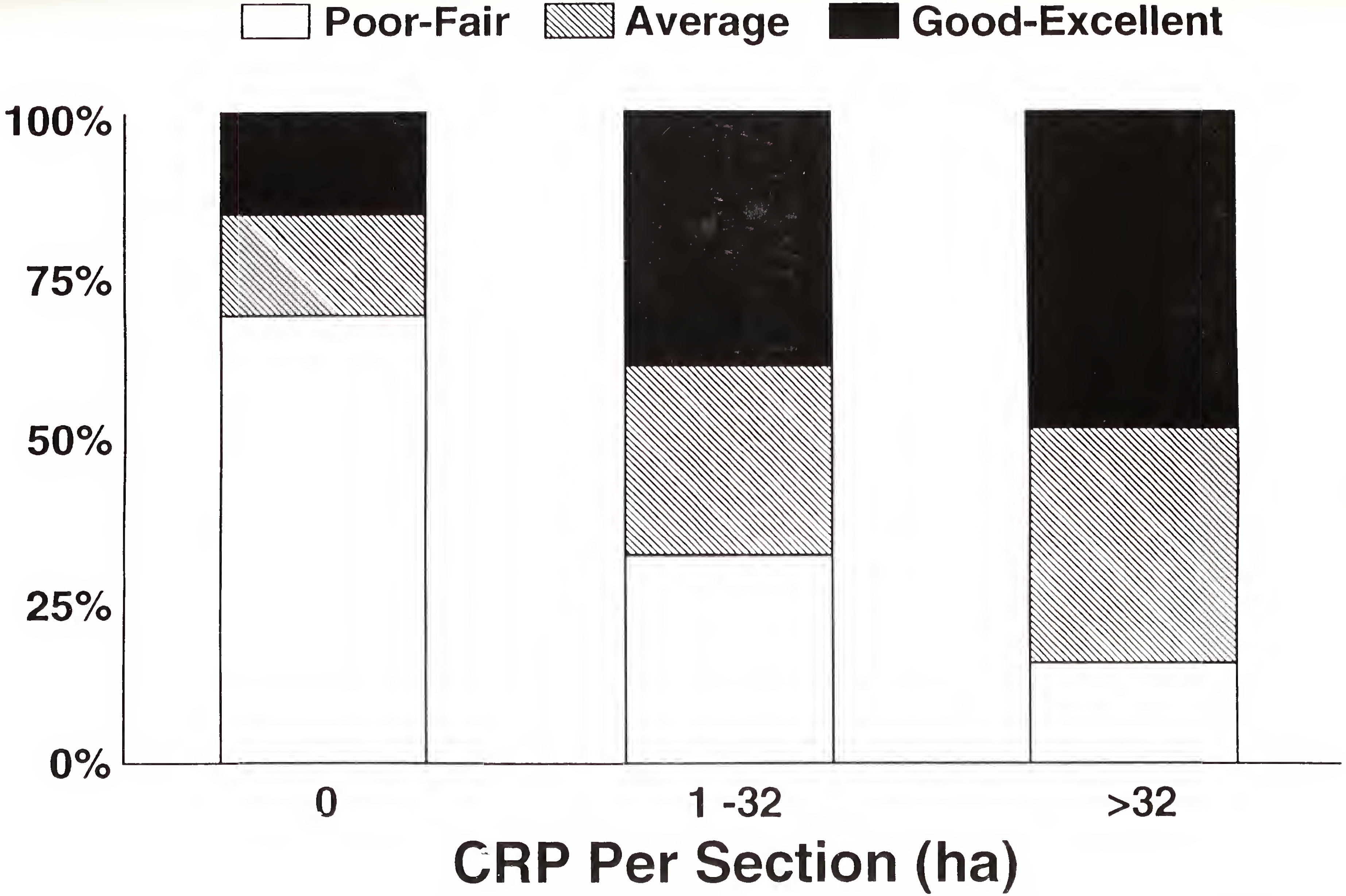

Figure 3. Prior bobwhite habitat quality in sections with varying amounts of CRP, Hamilton County, Illinois.

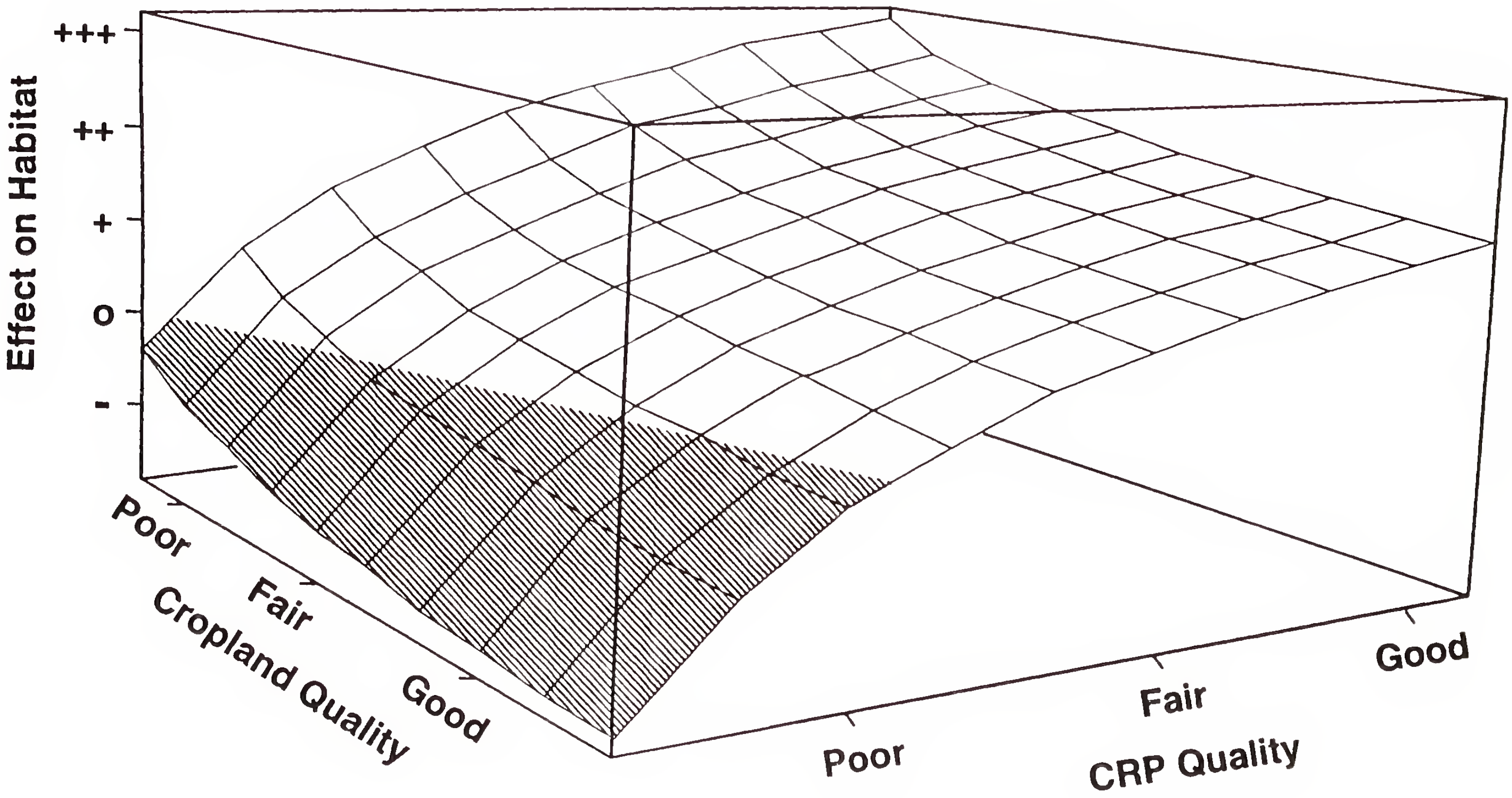

Figure 4. The relative effect of CRP on bobwhite habitat quality given various combinations of CRP and cropland quality, Hamilton County, Illinois (shaded portion of response surface indicates negative effect).

STUDY NO. 3: **Bobwhite Habitat Evaluation in Relation to Farm Programs, Land-Use Practices and IDOC Habitat Initiatives**

JOB 3.1A (SIU): **Bobwhite Management Strategies**

Prepared by:

John L. Roseberry and Bryan J. Richards
Cooperative Wildlife Research Laboratory
Southern Illinois University-Carbondale

NEED:

Effective wildlife management and land use planning require the ability to inventory, analyze, and interpret land cover and habitat information at various scales and resolutions. In the past decade, both research and management emphasis has been focused on the development and use of models as a means of objectively assessing wildlife habitat (Verner et al. 1986). Models can be used to a) assimilate and structure existing knowledge, b) assess potential carrying capacity, c) identify critical deficiencies, and d) predict responses to management and habitat alterations. At the local or site level, habitat parameters can often be directly measured; however, at the landscape or broader scale, unique problems arise in the collection, processing, and interpretation of data. Fortunately, techniques have emerged from remote sensing and computer technologies to address these problems (Mayer 1984), specifically in the area of satellite multispectral data classification and computer Geographical Information Systems (GIS).

Emerging agricultural programs and policies provide opportunity for improving and restoring upland wildlife habitat (Jahn and Schenck 1991). To maximize this potential, wildlife agencies need to exploit the developing technologies of remote sensing, GIS, and habitat modeling. More specifically, managers and biologists at the regional and district levels must be able to provide sound recommendations and input to private landowners, other resource agencies, and their own administrators. To do this, they need ready access to reliable information relating to habitat distribution and attributes for particular sites, areas, and regions.

OBJECTIVES:

(1) To develop standardized methods for measuring and evaluating farmland bobwhite habitat over relatively large areas; and (2) to integrate this methodology into a management strategy for maximizing the potential contribution of farm program opportunities and management initiatives for enhancing bobwhite habitat.

REVIEW:

Data Acquisition

The need to acquire land cover information over relatively large geographic areas implies that data must be remotely sensed as opposed to being directly recorded. Most remote sensing systems applicable to natural resource inventories obtain information about the earth's surface by measuring emitted or reflected electromagnetic energy from an aerial platform

(aircraft or satellite). Electromagnetic energy can be recorded either photographically (aerial photography) or electronically (air videography or satellite sensors).

Aerial Photography.--Aerial photography is the oldest, simplest, and most familiar method of gathering remotely sensed land cover information (Campbell 1987). Modern aerial photography usually involves large format metric (or cartographic) cameras designed to minimize geographic distortion of land surface features. Common film formats include 23 x 23 cm (approximately 9 x 9 in) and 5.7 x 5.7 cm (approximately 2.5 x 2.5 in). Standard 35 mm film (24 x 36 mm actual format) has also been used for specialized purposes, although its utility for remote sensing purposes is limited (Campbell 1987). A variety of films are used including black and white (panchromatic), black and white infrared, color, and color infrared. These films are sensitive to different ranges of wavelengths along the electromagnetic spectrum and thus produce different pictorial representations of the area being photographed and capture varying amounts of spectral information (Campbell 1987, Mayer 1984).

Black and white (BW) aerial photographs (prints) are available from the Agricultural Stabilization and Conservation Service (ASCS) at scales of 1:20,000 to 1:40,000. Coverage is usually flown on a county by county basis on a 7-year cycle, dating back to the late 1930's. Coverage of National Forest lands are available from the United States Forest Service (USFS) at scales of 1:20,000 to 1:40,000 dating to 1934. Standard

coverage obtained during the 1960's, however, was at 1:15,840 (Anderson et al. 1980). Complete 1988 coverage of Illinois (1:40,000 scale Markhurd contact prints or enlargements) are also available through the Illinois Department of Transportation.

Color infrared (CIR) aerial photography (prints, negatives, transparencies, enlargements) is available from the United States Geological Survey (USGS) Earth Resources Observation System (EROS) Data Center, Sioux Falls, SD. The National Aerial Photography Program (NAPP) existed from 1980 to 1986 and produced 9-inch prints and positive transparencies at a 1:58,000 scale. Coverage of the conterminous 48 states was virtually complete. Project specifications were changed in 1986 and the program was renamed National High Altitude Photography (NHAP). Coverage of the United States in scheduled for completion in 1995.

Another periodic source of remotely-sensed land cover information is from ASCS compliance slides. These are color or color-infrared aerial 35 mm slides (1:70,000 scale) centered on each political section of land and taken annually. The quality of the photographs varies from poor to excellent and back-dated photography is often not available.

Video Imagery.--Video imaging has emerged as a natural resource assessment tool over the past several years. No repository for video imagery exists and data are typically gathered on an individual project basis (Everitt and Nixon 1985). Numerous video formats have been used including multi-spectral black and white with visible/near infrared capabilities, color-infrared, normal color, black and white near infrared, and

thermal infrared (Everitt et al. 1990). Positive aspects of air video include real-time monitoring capability, immediate availability of the digital signal for visual interpretation and digital processing, and relatively low cost imagery (after initial equipment expense) (Everitt et al. 1990). Additionally, a sound track is usually available for identifying features of interest (Lillesand and Kiefer 1987). Negative considerations include decreased resolution with respect to aerial films, limited availability of immediate hard copy of images, and the necessity of frame-grabbing capabilities for digital analysis.

Satellite Imagery.--Landsat 5 is the most recent in the Landsat (originally ERTS) series of satellites devoted to earth resources applications (Lillesand and Kiefer 1987). Originally designed and operated by the National Aeronautics and Space Administration (NASA), images are now available through EOSAT, a private corporation in Lanham, MD (Campbell 1987). Landsat 5 carries 2 imaging devices, the Multispectral Scanner (MSS) and the Thematic Mapper (TM). The Multispectral Scanner collects information in 4 spectral channels (green, red, and 2 near-infrared) at a ground resolution of 79 m^2. The Thematic Mapper collects data in 7 spectral regions: blue (0.45-0.52 μm), green (0.52-0.60 μm), red (0.63-0.69 μm), near infrared (0.76-0.90 μm), 2 mid-infrared (1.55-1.75 and 2.08-2.35 μm), and thermal infrared (10.5-12.5 μm). The latter band is recorded at a ground resolution of 120 m^2, the rest at 30 m^2 resolution. The TM thus provides more spatial detail and spectral information than does the MSS (Lillesand et al. 1985). The TM spectral channels were

specifically selected for maximum discrimination of vegetation type and vigor, plant and soil moisture measurements, and differentiation of clouds and snow (Lillesand and Kiefer 1987). Both TM and MSS images are parallelograms approximately 185 km on a side (movable quarter scenes approximately 92.5 x 92.5 km can also be purchased). Orbit characteristics of Landsat 5 result in repetitive coverage of each earth scene every 16 days (Jensen 1986).

The French Systeme Pour l'observation de la Terre (SPOT) satellite first became operational in 1986. The platform carries 2 identical imaging devices referred to as High Resolution Visible (HRV) instruments, which are operable in either panchromatic or multispectral modes. In panchromatic mode, sensors gather information across a single broad spectral band (0.51-0.73 μm) at 10 m ground resolution. In multispectral mode, information is collected in green (0.50-0.59), red (0.61-0.68), and near infrared (0.79-0.89) channels at 20 m resolution. Each HRV has an imaging width of 60 km; the 2 devices overlap slightly in coverage, resulting in images maximally 117 km in width. Typical purchased SPOT scenes are 60 x 60 km. Orbit characteristics result in overhead repeat coverage every 26 days. However, the satellite is equipped with pointable optics that allow oblique angle repeat coverage at approximately 2.5-day intervals.

Selection of Media

Selection of a remote sensing system and specific product for a particular project depends on a variety of factors

including desired scale (extent and resolution of coverage), level of classification required, type of interpretation to be attempted (visual vs. computer-aided), frequency of coverage, cost, ease of data transfer, and availability.

Low level (1:1,000) aerial photographs with 0.3 m resolution are ideal for gathering detailed habitat information (e.g. vertical and horizontal layering) for small scale projects (<40 ha). Medium altitude (1:10,000) photographs with ground resolution of 0.3-1.5 m are suitable for small to medium sized projects (<400 ha) where information such as identification of individual tree species and crown measurements is required. High altitude photographs (1:30,000 to 1:120,000) with ground resolution of 3-5 m are best suited to large-scale projects (>400,000 ha) and provide information about spatial phenomena (patch shape and size, interspersion, etc.) and community-level interactions (Mayer 1984). Conventional aerial photography (BW, color, CIR) conveys relatively minimal spectral information in comparison to multispectral satellite imagery. However, the inherently low resolution (30 m for TM, 79 m for MSS) makes satellite imagery suitable only for large-scale projects where detailed, site-specific information is not required.

Another consideration of media selection is the required or desired type and level of classification. Many state and federal agencies use a hierarchical classification scheme devised by the USGS and described by Anderson et al. (1976). Level I (urban, agricultural, rangeland, forested, water, wetland, and barren categories) was designed for coarse land use assessments using

low resolution media. Level II categories (e.g. deciduous, evergreen, and mixed divisions of Level I forest) are more detailed and designed for use with higher resolution images. Level III categories are user-defined subdivisions (species or species assemblages) of Level II categories and typically require high resolution (e.g. medium altitude CIR) photography to assess (Campbell 1987). With regard to satellite imagery, reasonable accuracies have been achieved using TM data to resolve Level I and some Level II categories; accuracy is lower, however, for Level III categories (Ormsby and Lunetta 1987, Moore and Bauer 1990).

The type of interpretation to be conducted (e.g., visual or computer-assisted) is another factor to be considered when selecting the data-collection media for a particular project. Aerial photography is amenable to direct visual interpretation (Avery 1977), but must be converted to digital format for computerized assessment (Lillesand and Kiefer 1987). This can be accomplished through optical scanning of transparencies or positive prints, or by manually tracing feature boundaries with a digitizing tablet and cursor. Satellite imagery is particularly suited to computer-assisted interpretation because it is already in digital format when acquired.

Data Processing

Remote sensing, especially from satellite multispectral sensors, can generate large quantities of data. For example, an unclassified (7 channel) TM image of a 100 km X 100 km area would require about 78 mb of storage and a classified (1 channel) image

about 11 mb. This amount of data presents special problems of storage, manipulation, retrieval, and display. Fortunately, there are a number of powerful computer software packages called Geographical Information Systems (GIS) designed to accomplish these and other tasks relating to the integration of locational (spatial) and attribute (descriptive) data from surface features on earth (Burrough 1986).

In order to be useful, satellite data must first be georeferenced or geocoded i.e., geographically referenced to either physical features or a coordinate system on the earth's surface. Next, the data must be classified, i.e. converted from spectral to information classes. There are 2 primary types of classification procedures: supervised and unsupervised. In the former, areas of known type are identified on the image and designated as "training areas" or "prototypes." All categories of interest must be represented by at least 1 training area. Remaining pixels are then classified automatically by comparing their individual spectral attributes to each prototype using various mathematical algorithms such as minimum distance, parallelepiping, or maximum likelihood (Lillesand and Kiefer 1987). Unsupervised classification involves the creation of spectral classes by statistically clustering pixels into natural groupings based on similar spectral characteristics. These spectral classes can then be identified and labeled based on ground reference data. A combination of these 2 approaches is called hybrid classification or guided clustering. In this approach, several training areas are selected, each containing a

number of different cover types. Each training area is then clustered independently and similar clusters from different areas are combined and used as training sets to classify the entire image. Special forms of unsupervised classification, e.g., Principal components, Kauth's Tasseled Cap, are used to reduce the dimensionality of data sets and make display, analysis, and manipulation more manageable (Skrdla 1991).

There are 2 basic ways of encoding and storing geographic information including classified satellite imagery. These are the grid cell or raster method and the polygon or vector method. In the raster format, data are stored in a 2 dimensional (column-row) matrix with each grid cell or picture element (pixel) representing a particular area of the image. A value or code is assigned to each pixel representing the prevailing land-use type in that land area. In vector format, areas are delineated and identified by points, lines, or polygons. Vector storage generally provides superior mapping capabilities whereas the raster format is more efficient for certain analytical procedures including habitat modeling and manipulation with programming languages such as FORTRAN (Burrough 1986, Krumm et al. 1991).

Habitat Evaluation

Several northern bobwhite (Colinus virginianus) habitat models have been described including the US Fish and Wildlife Service HSI model for northern bobwhite (Schroeder 1985), the Missouri Department of Conservation's WHAG (Urich et al. 1984) and PATREC (Dailey 1989) models, and empirical regression models from Tennessee (Schultz and Brooks 1958, Exum et al. 1982),

Indiana (Backs 1981), and Virginia (Stauffer et al. 1990). Of these, only the Backs and Exum models used remotely-sensed data (direct interpretation of black and white aerial photographs) and only the latter model was designed to link with a GIS. The potential utility of developing habitat models that utilize remotely-sensed data, especially digital multispectral satellite imagery amenable to computer-aided manipulation and classification, has been recognized for some time (Marmelstein 1978, Lund et al. 1978, Mayer 1984, 1986). Several such models have been developed for various species including the grizzly bear, Ursus arctos horribilis, (Craighead 1980), moose, Alces alces, (Laperriere 1980), elk, Cervus elaphus, (Bright 1981, Isaacson et al. 1982, Leckenby et al. 1985), lesser prairie chicken, Tympanuchus pallidicinctus, (Cannon et al. 1982), kestrel, Falco sparverius, (Lyon 1983), white-tailed deer, Odocoileus virginianus, (Ormsby and Lunetta 1987), Eastern wild turkey, Meleagris gallopavo, (Donovan et al. 1987), and wood stork, Mycteria americana, (Hodgson et al. 1988).

Regardless of target species, most habitat models key on 3 aspects of habitat - composition, attributes, and interspersion. With models that utilize remotely-sensed data, especially data that is automatically or semi-automatically classified, selection of habitat components to be considered by the model is determined in large part by limitations of the imagery and/or classification procedures. For example, if hay, pasture, and CRP fields cannot be differentiated, then the model must use a broader category of "grassland". Mayer (1986) suggested that model developers use

variables that can be easily identified and measured with remote sensing tools. Payne and Long (1986) described ways in which existing models can be adapted to utilize such data.

Use of remote sensing data entails a tradeoff or compromise between extent and resolution of coverage. Certain attributes of cover types greatly affect their utility as habitat, yet these cannot always be delineated from remotely-sensed data, at least not from single season images. For example, the composition of grasslands (e.g. mixed warm season grasses and forbs vs fescue monoculture), the successional stage of oldfields, and the understory characteristics of woodlands. Several options exist in these situations. Variables reflecting "quality" of habitat components can treated as constants in the model with fixed values based on existing knowledge or assumptions. An alternative is to use an interactive model to query and accept user input regarding various aspects of habitat components (if the user does not know, values can default to "average" conditions).

The spatial relationships (interspersion, juxtaposition) among habitat components is a critical element of wildlife habitat, especially for low mobility species such as bobwhite (Stoddard 1931, Edminster 1954). Various methods have been developed to quantify "edge" and/or interspersion including direct measurement (Hanson and Miller 1961, Roseberry and Klimstra 1984), cover changes along line transects (Baxter and Wolfe 1972, Brooks and Scott 1983, Schuerholz 1974, Roseberry 1979), shape indices (Patton 1975, Roller 1978), and minimum

distance between cover types (McCall 1979, Backs 1981, Schroeder 1985, Ormsby and Lunetta 1987). For the most part, these above techniques require manual measurements from maps or aerial photographs and are therefore limited to relatively small areas. Computer-assisted analysis of satellite imagery has led to the development of algorithms and indices for assessing diversity and spatial patterns on a landscape or regional scale (e.g. Milne 1988, DeCola 1989, Turner 1989). Useful indices of edge and interspersion/juxtaposition amenable to computer manipulation of grid cell (raster) data have been described by Mead et al. (1981), Heinen and Cross (1983), and Lyon et al. (1987).

APPROACH

Land Use and Habitat Classification

Hamilton County in southeastern Illinois was selected for a pilot study to determine the feasibility of evaluating bobwhite habitat on a relatively large scale using remotely-sensed data. The purpose of this study phase was not to develop classification procedures and protocols applicable on a statewide basis, but to create an accurate classified image that could be used to devise and evaluate procedures for linking habitat models with remotely-sensed land cover data.

Woodlots, hedgerows, oldfields, intertilled croplands (corn, soybeans, milo), small-grain fields (winter wheat), and grass/legume areas (hay, grass, pasture, CRP) were ground surveyed over approximately 30% of Hamilton County during August-September 1989. Ground reference data were delineated on acetate overlays of high altitude color infrared photographs (4 April

1988; scale 1:21,120) obtained from the USGA EROS Data Center. A preprocessed Landsat 5 TM image covering Hamilton County (17 June 1989) was purchased from EOSAT Corporation. Initial image processing was conducted by Ducks Unlimited (DU) Habitat Inventory and Evaluation Program, Long Grove, IL. The Landsat quarter scene was reduced dimensionally from 6 spectral bands to a single channel digital matrix consisting of 228 spectral classes using unsupervised principal components and maximum likelihood classification techniques. Subsequent classification of the Landsat scene was conducted at Southern Illinois University at Carbondale using Earth Resources Laboratory Application Software (ELAS) (Graham et al. 1985) as modified by DU (Koeln et al. 1986).

Digital spectral classes within known land-use areas were grouped into land-use categories (training classes) and extrapolated to all areas within Hamilton County on the Landsat scene (inclusive of a 0.8-km buffer zone around the county). Training classes were developed for small grain, intertilled cropland, grass/legume, water and deciduous forest categories.

Training class, ground-truth, and aerial photographic data were then used to manually edit (digitize) all land-use features on the scene. The editing process entailed tracing all object (fields, woodlots, etc.) borders within the county and designating land use for each object into one of the following categories: (1) intertilled cropland, (2) grass/legume, (3) deciduous forest, (4) small grain, (5) oldfield, (6) water, (7) developed (urban areas and major roads), (8) hedgerow, (9)

drainage (rivers and major drainage channels), (10) barren (devoid of vegetation), (11) farmstead, and (12) coniferous forest (mainly plantations). Hedgerows (many of which were not apparent on the Landsat scene) were defined as linear features comprised mainly of woody vegetation that were at minimum visible on aerial photographs and were at maximum 1 pixel (30 m) wide on the Landsat scene. Conservation Reserve Program (CRP) fields were added separately to the classified image as it was not possible to distinguish this land-use type from other grasslands using the multispectral satellite image. Location of all CRP land in the county was obtained from maps on file with the Hamilton County ASCS office and transferred to acetate overlays of the color infrared photographs. Individual CRP fields were then located on a graphic display of the classified satellite image and the corresponding digital data file changed to the CRP category using a RASTER EDITING procedure of Map and Image Processing System (MIPS) software (Miller et al. 1989).

Integration of Classified Images with Evaluation Procedures

After a remotely-sensed image has been classified, it is often desirable to analyze it outside the GIS environment. This can be accomplished by first exporting the classified image as a text (ASCII) file. Most raster-based GIS packages can accomplish this under a variety of formats and structures. In the present study, a classified image of Hamilton County, Illinois (at 30 x 30 m ground resolution) plus a 0.8-km mile buffer zone was exported as a 1-dimensional array of length 1,441,600 (logical width = 1060; logical height = 1360). The land-use type in each

30 x 30 m pixel was represented as an alphabetic character occupying 1 byte of storage. Two northern bobwhite habitat models (Appendix A) were developed to access the exported land cover data, extract user-defined areas of interest, qualitatively and quantitatively assess habitat, and identify limiting factors. Computer code (Microsoft® Fortran Version 5.0) for the implementation of Model I is provided in Appendix B.

As an adjunct corollary to this Job and Federal Aid Project W-63-R(SI)-35, Job B (Richards 1992, Woolf and Roseberry 1992), PC-based software was developed which not only links classified land cover data bases with habitat models, but also facilitates interactive graphic display and manipulation of the data. Preliminary versions of the program were demonstrated at the 53rd Midwest Fish and Wildlife Conference (Richards et al. 1991), Quail III: National Quail Symposium (Richards and Roseberry 1992), and the 1992 Annual Meeting of the Illinois Chapter-the Wildlife Society. This concept, plus the other products, techniques, and approaches from Job 3.1A will be developed and expanded during Phase II of the Cooperative Upland Wildlife Research Project (W-106-R; Study No. 1) to produce a management-oriented computer workstation for the storage, retrieval, and interpretation of habitat and habitat-related information.

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APPENDIX A. Description of northern bobwhite habitat models designed to utilize remotely-sensed land cover data.

The general structure and logic of Model I is shown in Figure 1. The model utilizes the general land cover categories of woods, cropland, grassland, oldfield and nonhabitat. The contribution and value of each of these in providing for bobwhite life requisites (food, cover, nesting) is based on relative amounts of each cover type in relation to assumed optimum and attributes such as type, management, successional stage, etc. An overall habitat suitability index is then determined by combining the values of food, cover, and nesting with a spatial index that measures the interspersion and juxtaposition of habitat components. The assumptions and logic of the model are described below.

Habitat Composition

Optimal bobwhite habitat was assumed to exist when land cover consisted of ≥ 15% woods, ≥ 30% cropland, ≥ 20% grassland, and ≥ 25% oldfields. Suitability index values based on relative amounts of woods (SIFA), cropland (SICA), grassland (SIGA), and oldfield (SIOA) were then computed using curves shown in Figure 2.

Habitat Quality and Value

The potential value of various land cover types was assumed to be a function of their relative amount in relation to optimum (described above) and their quality in relation to optimum.

Woods.--The quality of wooded areas as bobwhite habitat (QWOOD) was assumed to be related to the following attributes:

percent canopy cover (SIFC), size or age class (SIFS), frequency of flooding (SIFF), and intensity of grazing (SIFG). A 0-40% canopy coverage was considered optimum with 41-70% of intermediate value, and > 70% of low value (Fig. 3). Saw timber was considered preferable to pole or smaller timber. Woods that were never flooded or grazed were considered optimum whereas those that were frequently flooded or heavily grazed were considered to be of little value. The value of woods (VWOOD) was then computed as a multiplicative function of relative amount (SIFA) and quality of wooded acreage:

$$QWOOD = (SIFC * SIFS * (MIN(SIFF, SIFG)))^{0.333}$$

$$VWOOD = SIFA * QWOOD$$

Cropland.--Quality of cropland was assumed to be a function of type of crop planted (SICT) and its overwinter management (SICM). Grains such as corn, soybeans, and milo were considered superior to small grains such as wheat or oats while fiber-producing crops were considered of little value (Fig. 4). In terms of tillage practices, unharvested fields were considered most valuable and fall plowed fields least valuable (Fig. 4). Quality was then represented as the geometric mean of SICT and SICM with the latter (overwinter management) assumed to be twice as important than the former. The overall value of cropland (VCROP) was then computed as a multiplicative function of relative optimal amount (SICA) and quality (QCROP):

$$QCROP = (SICT * SICM^2)^{0.333}$$

$$VCROP = SICA * QCROP$$

Grassland.--Quality of existing grasslands was determined by the predominant vegetative type (SIGT) and haying/grazing pressure (SIGM). Mixed warm season grasses and forbs were considered optimal followed by a warm season/cool season mixture, cool season grasses or legumes, monoculture other than fescue, and monoculture fescue (Fig. 5). Little or no haying or grazing was most favorable with grasslands subjected to heavy haying or grazing of little use. Value of grassland (VGRASS) for bobwhite habitat was then computed as a multiplicative function of relative optimal amount (SIGA) and quality:

$$QGRASS = (SIGT * SIGM)^{0.5}$$

$$VGRASS = SIGA * QGRASS$$

Oldfield.--The potential quality of existing oldfield cover as bobwhite habitat was based on prevailing successional stage. Individual suitability indices were determined separately for oldfield contribution as food (SIOF), winter cover (SIOC), and nesting cover (SION). Early seral stages were considered most valuable for food, mid stages for nesting, and late stages for cover (Fig. 6). The actual values of oldfields as food, winter cover, and nesting cover (VOLDF, VOLDC, VOLDN) was computed as the geometric mean of the relative optimal amount (SIOA) and quality in relation to the particular life requisite:

$$VOLDF = (SIOA * SIOF)^{0.5}$$

$$VOLDC = (SIOA * SIOC)^{0.5}$$

$$VOLDN = (SIOA * SION)^{0.5}$$

Life Requisites

Food.--The assigned value of food (VFOOD) is computed by summing the values of those cover types that contribute to this life requisite. Woods and grasslands are assumed to contribute only 10-20% as much as cropland and oldfields:

$$\text{IF } (SICA < 1.0) \text{ THEN } VFOOD = \mathrm{MIN}(1.0, (VCROP + VOLDF + (0.1 * VWOOD) + \mathrm{MIN}((1.0 - SICA), (0.2 * VGRASS))))$$
$$\text{ELSE } VFOOD = \mathrm{MIN}(1.0, (VCROP + VOLDF + (0.1 * VWOOD)))$$

Winter Cover.--Winter cover value (VCOVER) was assumed to be an additive function of the value of woods and oldfields as cover:

$$VCOVER = VWOOD + VOLDC$$

Nesting cover.--The value of nesting cover (VNEST) was obtained by summing the values of grasslands and oldfields as nesting cover. Cropland (regardless of type or overwinter management) was assumed to contribute very slightly to this life requisite:

$$\text{IF } (SIGA < 1.0) \text{ THEN } VNEST = \text{MIN}(1.0, (VGRASS + VOLDN + \text{MIN}((1.0 - SIGA), (0.2 * VCROP)))) \text{ ELSE } VNEST = \text{MIN}(1.0, (VGRASS + VOLDN))$$

A final, aggregated variable representing life requisite value (VHAB) was computed as the geometric mean of the respective values for food, cover, and nesting. Assuming a geometric function gives increased weight to low values and also means that if any 1 life requisite is missing (value = 0), the overall value is 0:

$$VHAB = ((VFOOD^{1.5}) * (VCOVER^{1.5}) * VNEST)^{0.25}$$

Spatial Relationships

Quantification of spatial relationships in Model I followed methods described by Heinen and Cross (1983). This approach is particularly amenable to computer manipulation of land cover data in raster (grid cell) format. Raw interspersion was first measured by counting the number of times that 2 adjacent (vertical, horizontal, or diagonal) pixels represented different land cover types. This sum was then divided by the maximum possible number of such edges in a square mile (23,328). The result was then assigned a suitability index (SII) based on the assumption that ≥ 35% of maximum was optimum (Fig. 7). The juxtaposition component of the spatial index was similar to the raw interspersion count except that a relative weight (0 - 1.0) was assigned to each type of habitat interface depending on its presumed importance to bobwhites (Table 1). An overall spatial suitability index (VSPA) was obtained by summing the weighted

contributions of the interspersion and juxtaposition components (latter assumed 2.33 times more important than former):

$$VSPA = (0.3 * SII) + (0.7 * SIJ)$$

Habitat Suitability Index

A final habitat suitability index (HSI) was calculated by taking the geometric mean of the computed values for combined life requisites (VHAB) and spatial relationship (VSPA) and adjusting it downward based on the amount of nonhabitat in the section:

$$HSI = ((VHAB * VSPA)^{0.5}) * (1.0 - (NH * 0.75))$$

A second bobwhite model (Model II) was developed that differed from Model I primarily in the way in which interspersion or edge was quantified. Instead of computing a juxtaposition index, Model II measured the distances from individual units (30 x 30 m pixels) of habitat to the closest complimentary habitat types (e.g. food to cover) and rated each unit based on proximity to a complimentary habitat type (e.g. food to cover). For example, individual units of woods were considered of maximum value if they were $\leq$ 60 m from a food source (cropland, early idle) and of no value if they were > 420 m from food (Fig. 8). The average value for all units of woods was then calculated and multiplied by the total proportion of woods to obtain the usable proportion. The value of woods for bobwhite was then assumed to be a multiplicative function of usable amount and quality. A similar procedure was used to determine the value of grassland and cropland. Grassland was considered of maximum value if it was $\leq$ 60 m from cover (woods, late idle) and of no value if it was > 400 m from cover. Cropland was considered optimum only if $\leq$ 30 m from cover and unusable if > 240 m from cover. All units of oldfield cover was considered useful regardless of distance to other habitat types. Model II also differs from Model I in that suitability index values are computed for each life requisite based on assumed optimums (this is analogous to the equivalent optimum approach used by USFWS HSI models). A composite life requisite variable (VHAB) was computed as follows:

$$VHAB = (SIFOOD * SICOVER * SINEST)^{0.333}$$

The final Habitat Suitability Index (HSI) was computed as a geometric mean of the suitability indices for life requisites and their interspersion with the former 4 times as important as the latter.

$$HSI = ((VHAB^{4}) * (SII^{1}))^{0.2}$$

Table 1. Juxtaposition coefficients for Bobwhite Habitat Model I.

	A	B	C	D	E	F
A	-	3.0	2.5	2.0	2.0	0.5
B		-	2.5	2.0	2.0	0.5
C			-	1.0	1.5	0.5
D				-	1.0	0.5
E					-	0.5
F						-

Land-Use Types

A Woods/hedgerow
B Oldfield
C Intertilled cropland
D Small grains
E Grassland
F Non-habitat

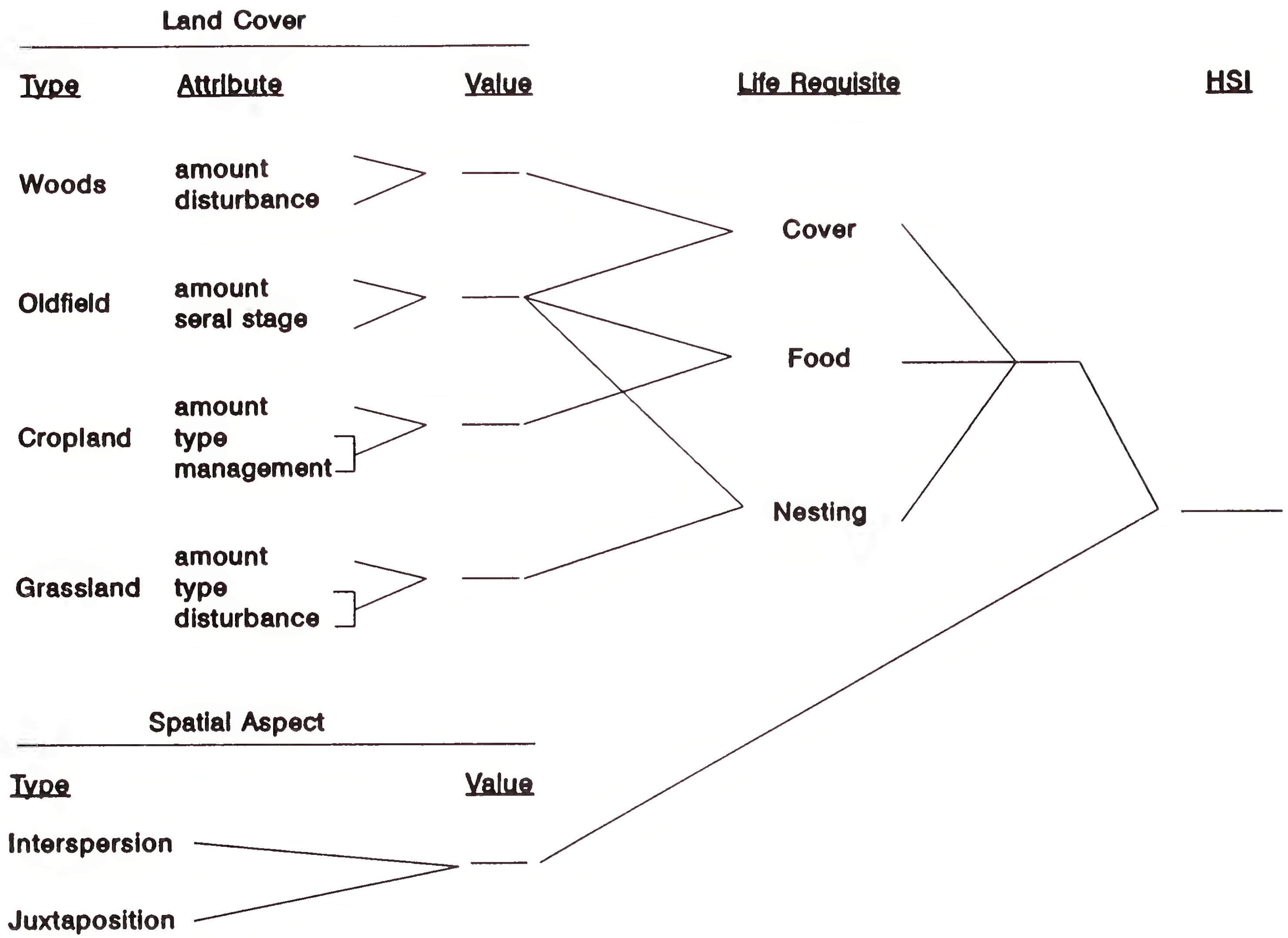

Figure 1. Basic structure of Bobwhite Habitat Model I.

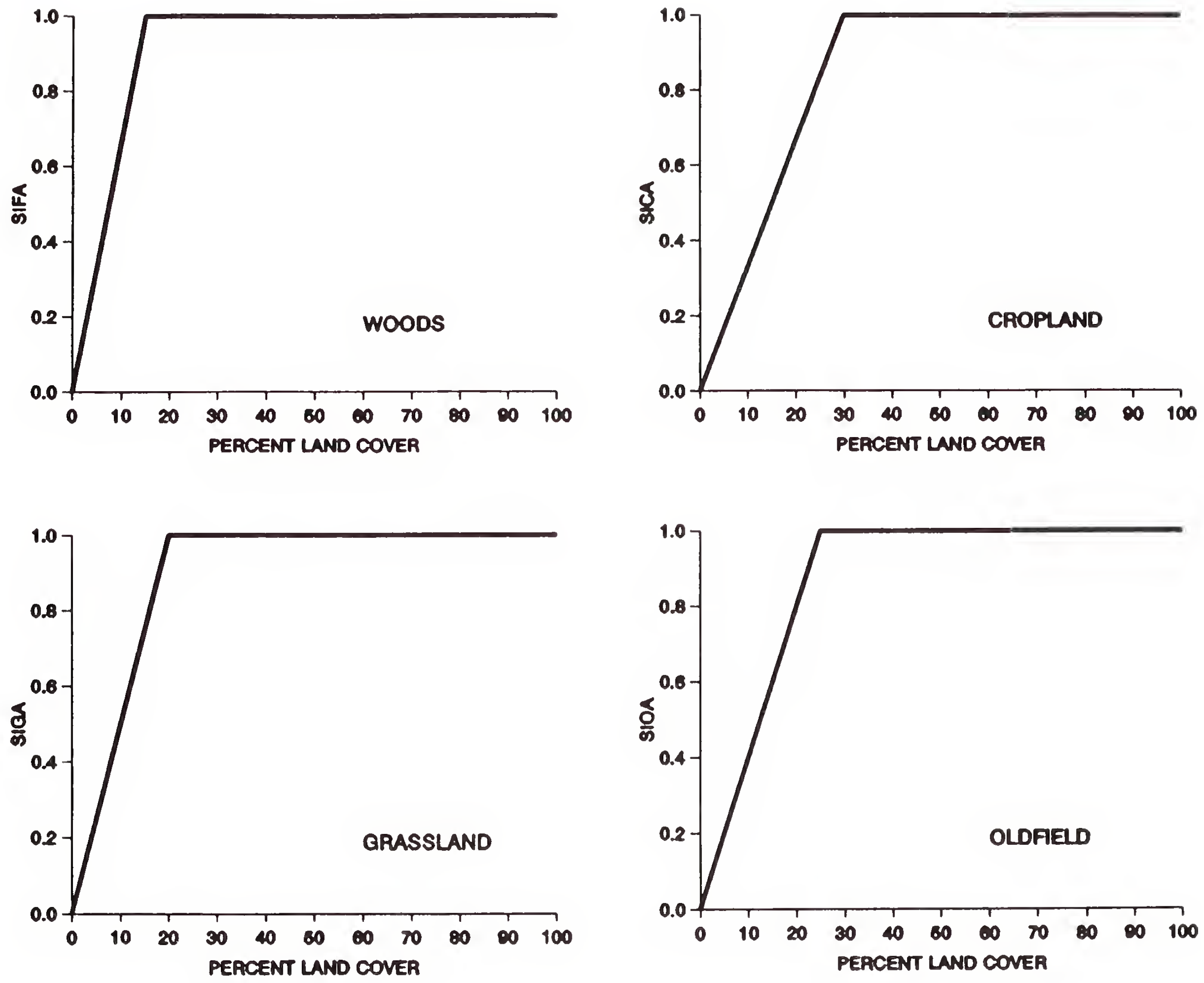

Figure 2. Suitability indices for habitat components.

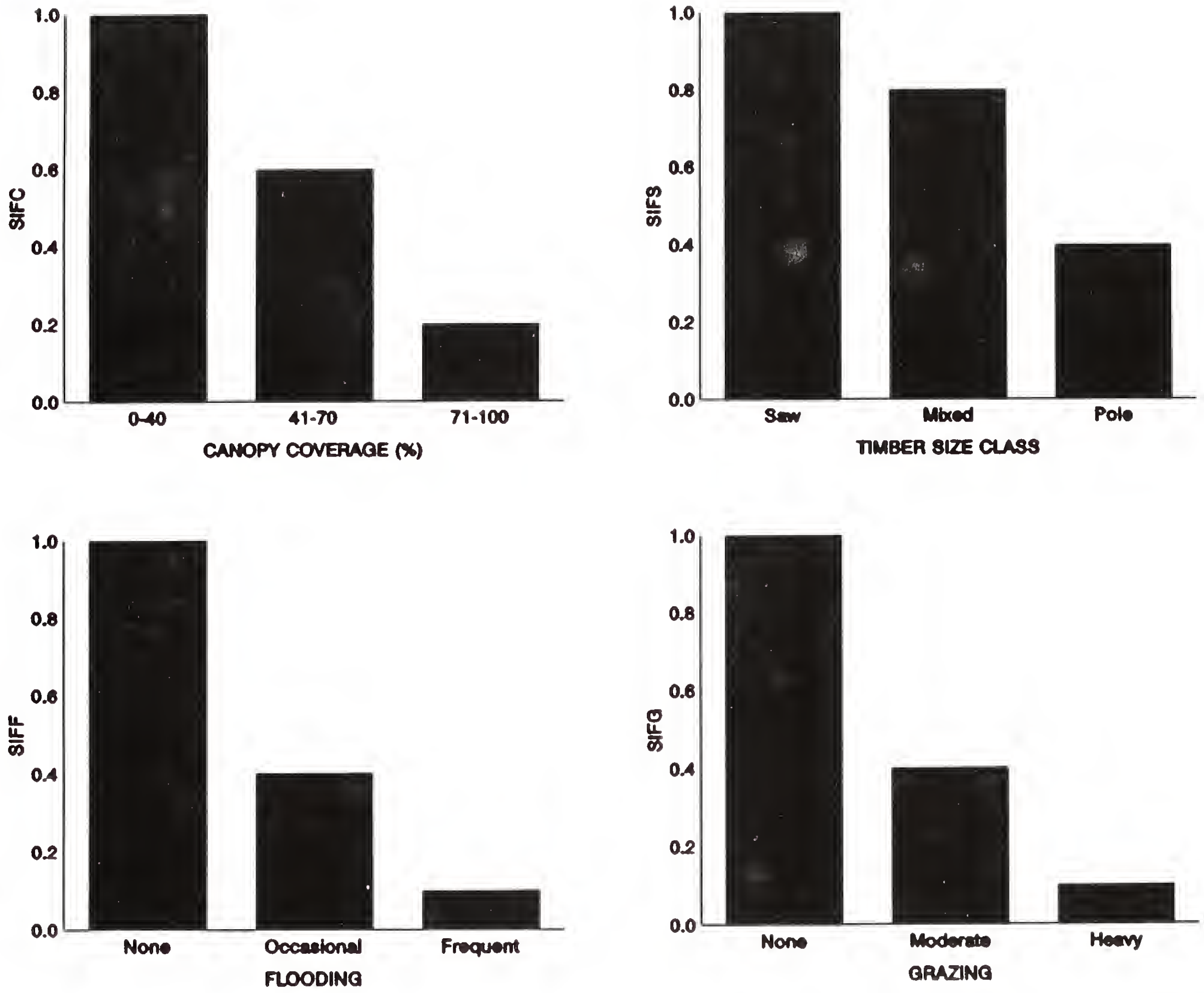

Figure 3. Suitability indices for forest characteristics.

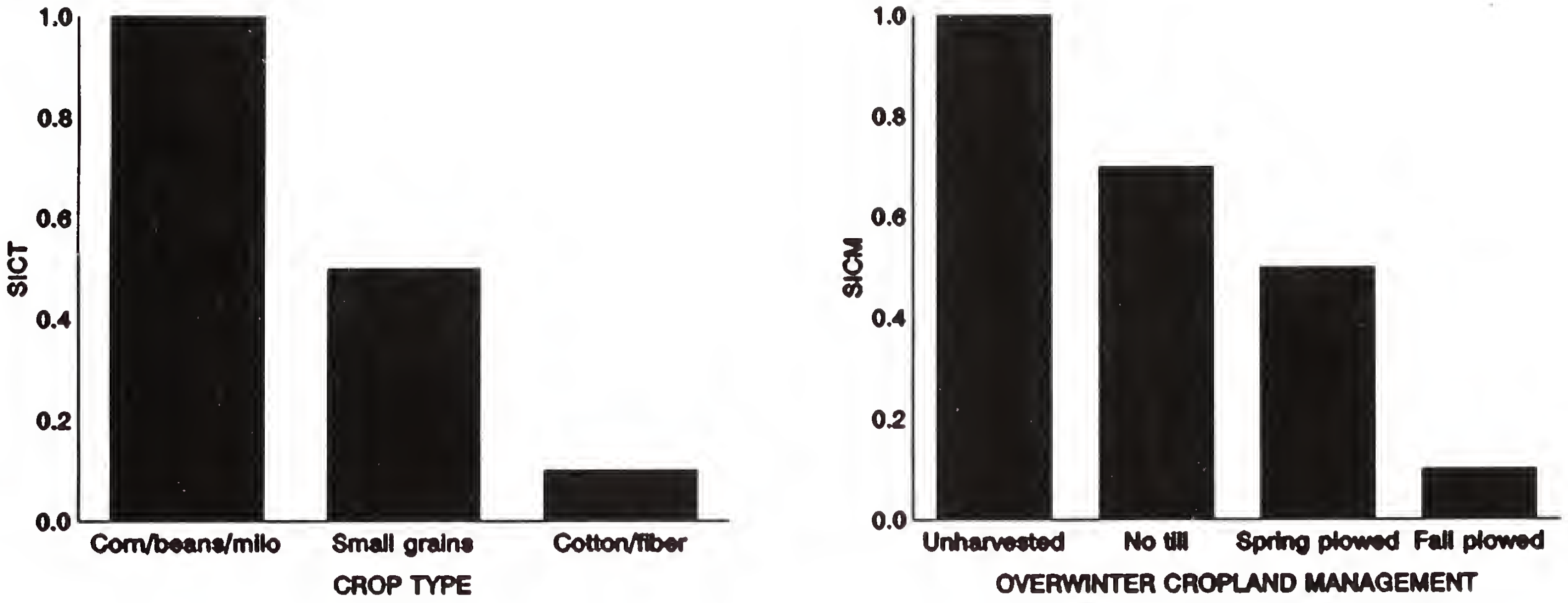

Figure 4. Suitability indices for cropland type and management.

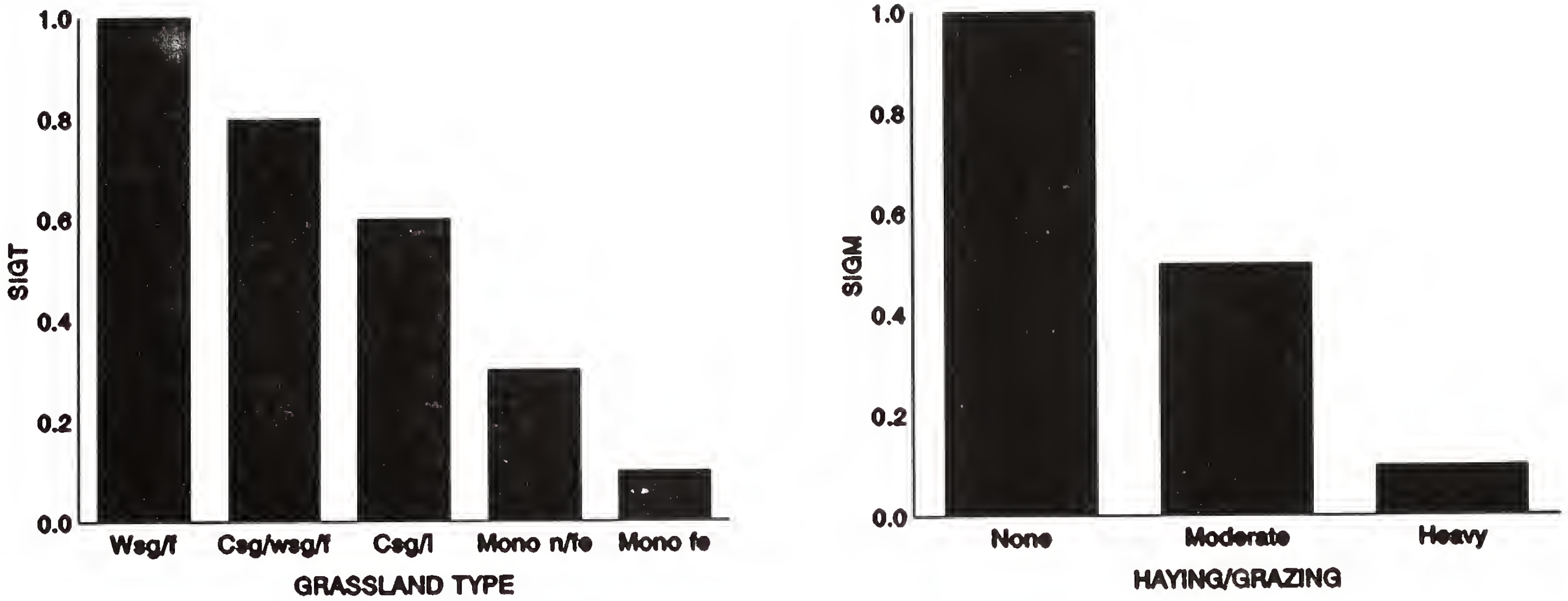

Figure 5. Suitability indices for grassland type and management (wsg/f = warm season grasses and forbs; csg/wsg/f = mixed grasses and forbs; csg/l = cool season grasses and legumes; mono n/f = monoculture not fescue; mono/fe = monoculture fescue).

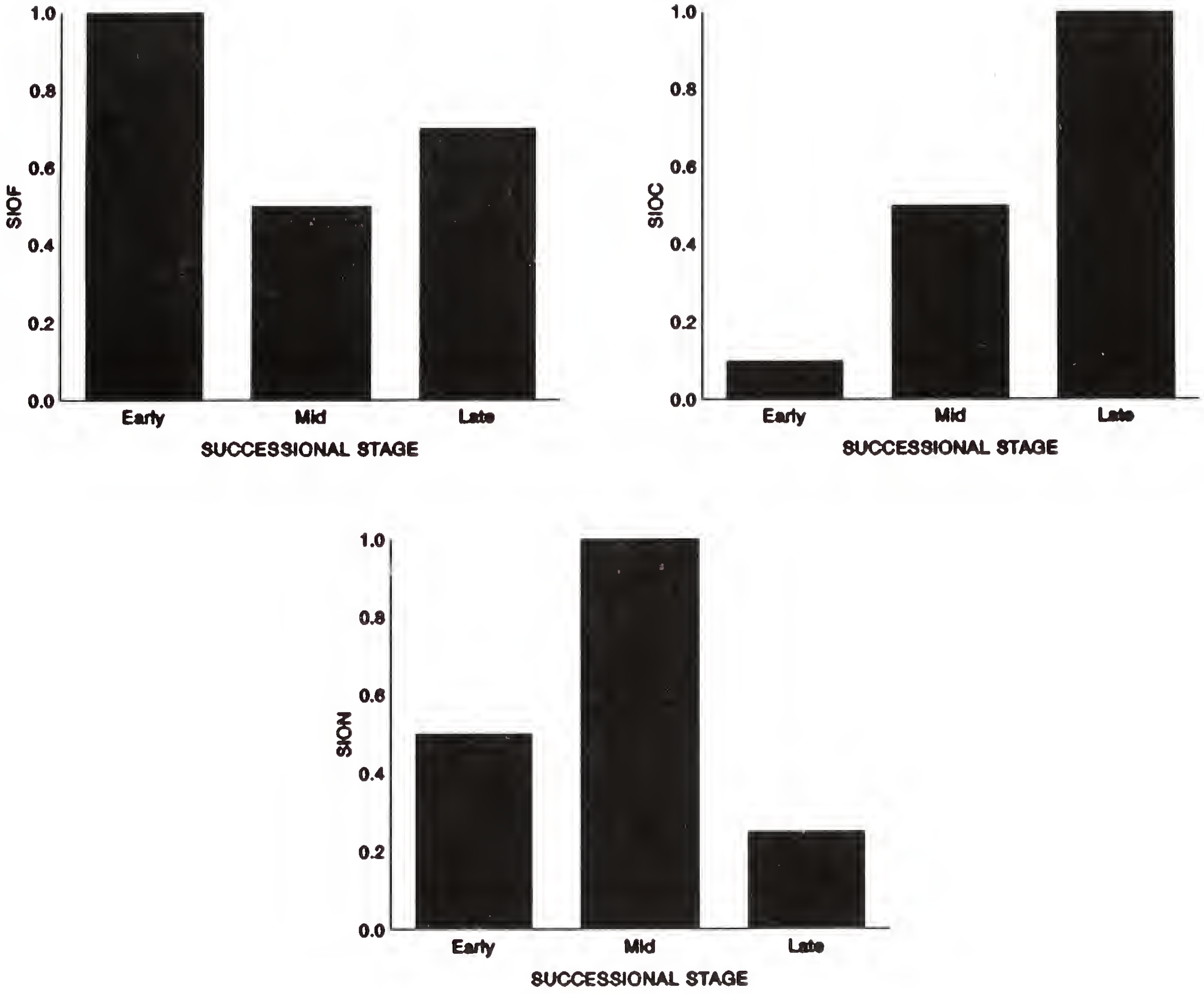

Figure 6. Suitability indices for oldfield successional stages.

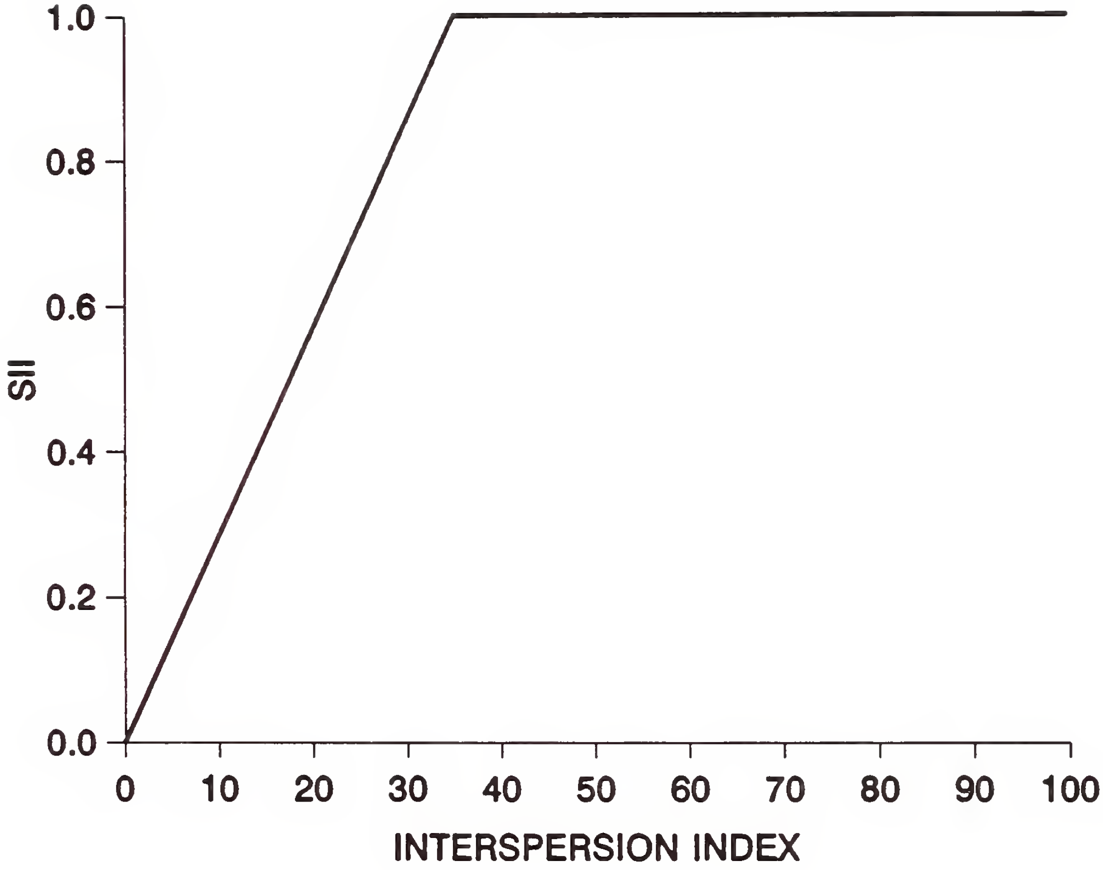

Figure 7. Suitability index for habitat interspersion.

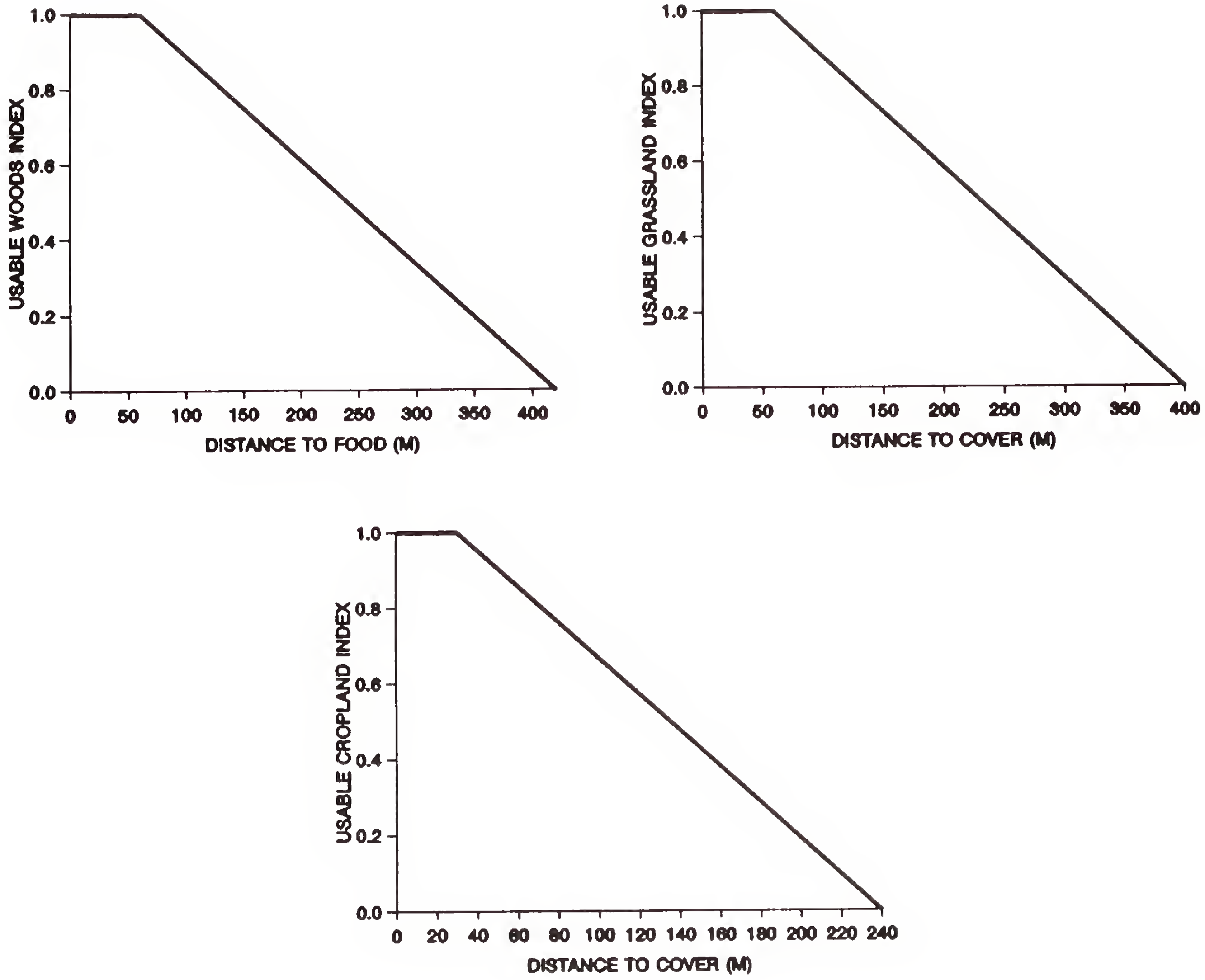

Figure 8. Suitability indices for minimum proximity distances.

APPENDIX B. Computer code (Microsoft® FORTRAN Version 5.0) for the implementation of Bobwhite Habitat Model I.

```
C
C
C                          VARIABLE LIST
C
C     BR =  identifies beginning record in FORTRAN READ statement
C     CT1 = proportion of cropland as corn, soybeans, or sorghum
C     CT2 = proportion of cropland as small grains
C     CT3 = proportion of cropland as fiber
C     E( ) = array of habitat types surrounding centroid pixel
C     GIS( ) = matrix of pixels representing classified area to be
C              modeled
C     HAB( ) = matrix of pixels representing habitat types area
C     HSI = final habitat suitability index
C     KA =  pixel count of CRP
C     KC =  pixel count of cropland
C     KF =  pixel count of forest
C     KG =  pixel count of grassland
C     KN =  pixel count of nonhabitat
C     KO =  pixel count of oldfield
C     KW =  pixel count of small grain
C     KX =  type of juxtaposition
C     NEDGE = count of raw edges
C     NJUX = total of weighted edge values
C     NV = difference between centroid and adjacent pixel types
C     NX = flag indicating adjacent or diagonal pixel
C     PA (AA) = percent (proportion) of CRP
C     PC (CA) = percent (proportion) of cropland
C     PF (FA) = percent (proportion) of forest
C     PG (GA) = percent (proportion) of grassland
C     PN (NA) = percent (proportion) of nonhabitat
C     PO (OA) = percent (proportion) of oldfield
C     PW (WA) = percent (proportion) of small grain
C     QCROP = quality index for cropland
C     QGRASS = quality index for grassland
C     QWOOD = quality index for forest
C     SICA = suitability index for cropland amount
C     SICT = suitability index for cropland type
C     SICM = suitability index for cropland management
C     SIFA = suitability index for forest amount
C     SIFC = suitability index for forest canopy cover
C     SIFF = suitability index for forest flooding
C     SIFG = suitability index for forest grazing
C     SIFS = suitability index for forest size class
C     SIGA = suitability index for grassland amount
C     SIGAN = suitability index for grassland amount (for nesting)
C     SIGM = suitability index for grassland management
C     SIGT = suitability index for grassland type
C     SIJ = suitability index for juxtaposition of habitat types
C     SII = suitability index for interspersion of habitat types
```

```
C    SIOA = suitability index for oldfield amount
C    SIOAN = suitability index for oldfield amount (for nesting)
C    SIOC = suitability index of oldfield for cover
C    SIOF = suitability index of oldfield for food
C    SION = suitability index of oldfield for nesting
C    THSI = gross habitat suitability index
C    VCOVER = value index for cover component
C    VCROP = value index for cropland
C    VFOOD = value index for food component
C    VGRASS = value index for grassland
C    VGRASSN = value index for grassland (for nesting)
C    VHAB = value index of habitat component
C    VOLDC = value index of oldfield for cover
C    VOLDF = value index of oldfield for food
C    VOLDN = value index of oldfield for nesting
C    VNEST = value index of nesting component
C    VSPA = value index of spatial component
C    VWOOD = value index for forest
C    XIS = mean number of raw edges
C    XIJ = mean juxtaposition weights
C    COL = column designation for northwest pixel of sub area to
C          be modeled
C    ROW = row designation for northwest pixel of sub area to be
C          modeled
C    CB = column designation for northwest pixel of sub area plus
C         buffer zone
C    RB = row designation for northwest pixel of sub area plus
C         buffer zone
C
C
C                  CLASSIFICATION AND HABITAT CODES
C
C            A = CRP                   1 = forest
C            B = barren                2 = hedgerow
C            C = cropland              3 = cropland
C            D = deciduous forest      4 = small grain
C            F = farmstead             5 = grassland
C            G = hay, pasture, etc.    6 = CRP
C            H = water                 7 = oldfield
C            O = oldfield              8 = nonhabitat
C            P = coniferous
C            R = hedgerow
C            S = drainage
C            U = urban
C            W = small grain
C
C
C                     SOURCE CODE AND COMMENTS
C
C ** Initializes habitat and classification matrices.
C
      INTEGER*1 HAB(108,108)
      INTEGER PHH,PHA,TN,RN,SE,COL,ROW,CB,RB,BR
      CHARACTER*1 GIS(108,108)
```

```
      CHARACTER*16 LF
      REAL NA
C
C ** Defines and opens a text file containing classified land use
C    data.
C
      OPEN(UNIT=2,FILE='C:/HABMODEL/HAM.TXT',ACCESS='DIRECT',
     +RECL=1, FORM='BINARY')
C
C
C ** Calls routine that identifies the sub area to be modeled and
C    returns its northwest coordinates.
C
      CALL INPUT(COL,ROW)
C
C ** Alters the coordinates to include a 0.5-mile buffer zone.
C
      CB=COL-27
      RB=ROW-27
C
C ** Extracts 2 x 2 mile square area from the classified image
C    file and puts it into a 108 x 108 element (pixel) matrix    C
  (1060 is the logical width of the classified image).
C
      DO J=1,108
         BR=(((RB-2)+J)*1060)+CB
         READ(2,REC=BR) (GIS(J,K),K=1,108)
      END DO
C
C ** Examines each pixel in square mile target area plus 0.5-mile
C    buffer zone and converts land cover classification to
C    habitat code.
C
      DO 200 J=1,108
         DO 200 K=1,108
            IF(GIS(J,K).EQ.'D'.OR.GIS(J,K).EQ.'P') HAB(J,K)=1
            IF(GIS(J,K).EQ.'R') HAB(J,K)=2
            IF(GIS(J,K).EQ.'C') HAB(J,K)=3
            IF(GIS(J,K).EQ.'W') HAB(J,K)=4
            IF(GIS(J,K).EQ.'G') HAB(J,K)=5
            IF(GIS(J,K).EQ.'A') HAB(J,K)=3
            IF(GIS(J,K).EQ.'O') HAB(J,K)=7
            IF(GIS(J,K).EQ.'S'.OR.GIS(J,K).EQ.'U'.OR.GIS(J,K)
     +      .EQ.'F'.OR.GIS(J,K).EQ.'B'.OR.GIS(J,K).EQ.'H')
     +      HAB(J,K)=8
200   CONTINUE
C
C
C
C ** Calls routine that computes and returns various areal
C    parameters for each habitat type.
C
      CALL AREA (HAB,FA,CA,WA,GA,AA,OA,NA,PHH,PHA,PF,PC,PW,PG,
     +PO,PN)
```

```
C
C ** Calls routine that computes suitability, quality, and value
C    indices for each habitat type and life requisite and returns
C    overall habitat value.
C
      CALL VALUE (FA,CA,WA,GA,AA,OA,VHAB,LF)
C
C ** Calls routine that computes and returns interspersion and
C    juxtaposition suitability indices.
C
      CALL SPATIAL (HAB,SII,SIJ)
C
C ** Calculates overall spatial component value from
C    interspersion and juxtaposition suitability indices.
C
      VSPA=(0.3*SII)+(0.7*SIJ)
C
C ** Calculates gross Habitat Suitability Index.
C
      THSI=(VHAB*VSPA)**0.5
C
C ** Calculates final Habitat Suitability Index by adjusting
C    gross HSI downward based on amount of nonhabitat in section.
C
      HSI=THSI*(1.0-(NA*0.75))
C
C ** Sends various statistics and parameters to routine for
C    outputting.
C
      CALL OUTPUT (TN,RN,SE,PHH,PHA,PF,PC,PW,PG,PO,PN,SII,LF,HSI)
      END
C
C
C
C ** Routine computes and returns various areal parameters for
C    each habitat type.
C
      SUBROUTINE AREA(HAB,FA,CA,WA,GA,AA,OA,NA,PHH,PHA,PF,PC,PW,
     +PG,PO,PN)
      INTEGER*1 HAB(108,108)
      INTEGER PHH,PHA
      REAL NA
C
C ** Initializes habitat-type pixel counters.
C
      KF=0
      KC=0
      KW=0
      KG=0
      KA=0
      KO=0
      KN=0
C
C
```

```
C ** Counts and records number of pixels in each habitat type
C    within square mile area.
C
      DO 100 J=28,81
         DO 100 K=28,81
            SELECT CASE(HAB(J,K))
               CASE(1,2)
                  KF=KF+1
               CASE(3)
                  KC=KC+1
               CASE(4)
                  KW=KW+1
               CASE(5)
                  KG=KG+1
               CASE(6)
                  KA=KA+1
               CASE(7)
                  KO=KO+1
               CASE(8)
                  KN=KN+1
            END SELECT
100   CONTINUE
C
C ** Calculates proportion of square mile section (2916 pixels)
C    in each habitat type.
C
      FA=KF/FLOAT(2916)
      CA=KC/FLOAT(2916)
      WA=KW/FLOAT(2916)
      GA=KG/FLOAT(2916)
      AA=KA/FLOAT(2916)
      OA=KO/FLOAT(2916)
      NA=KN/FLOAT(2916)
C
C ** Determines proportion of total area in nonhabitat and
C    converts to acres and hectares.
C
      PH=(KF+KC+KW+KG+KA+KO)/FLOAT(2916)
      PHH=PH*259
      PHA=PH*640
C
C ** Converts habitat proportions to percents for output and
C    returns to MAIN.
C
      PF=FA*100
      PC=CA*100
      PW=WA*100
      PG=(GA+AA)*100
      PO=OA*100
      PN=NA*100
      RETURN
      END
C
C
```

```
C ** Routine computes suitability, quality, and value indices for
C    habitat types life requisites and returns overall habitat
C    value.
C
      SUBROUTINE VALUE (FA,CA,WA,GA,AA,OA,VHAB,LF)
      CHARACTER*16 LF
C
C ** Assigns default values to habitat quality variables
C    in absence of user input.
C
      DATA SIFC,SIFS,SIFF,SIFG,SICT,SICM,SIGT,SIGM,SIOF,SION,
     +SIOC/11*0.5/
C
C ** Determines proportion of cropland in various types and
C    computes suitability index.
C
      CT1=0.0
      CT2=0.0
      CT3=0.0
      IF(CA.GT.0.0.OR.WA.GT.0.0) CT1=(CA/(CA+WA))*100.0
      IF(CA.GT.0.0.OR.WA.GT.0.0) CT2=(WA/(CA+WA))*100.0
      SICT=((CT1*1.0)+(CT2*0.5)+(CT3*0.1))/100.0
C
C ** Determines suitability indices for amounts of various
C    habitat types.
C
      IF(FA.LT.0.15) SIFA=(6.67*FA)
      IF(FA.GE.0.15) SIFA=1.0
      IF((CA+WA).LT.0.30) SICA=(3.33*(CA+WA))
      IF((CA+WA).GE.0.30) SICA=1.0
      IF((GA+AA).LT.0.20) SIGA=(5.0*(GA+AA))
      IF((GA+AA).GE.0.20) SIGA=1.0
      IF((GA+AA).LT.0.35) SIGAN=(2.86*(GA+AA))
      IF((GA+AA).GE.0.35) SIGAN=1.0
      IF(OA.LT.0.25) SIOA=(5.0*OA)
      IF(OA.GE.0.25) SIOA=1.0
      IF(OA.LT.0.35) SIOAN=(2.86*OA)
      IF(OA.GE.0.35) SIOAN=1.0
C
C ** Determines quality and value indices for various habitat
C    types.
C
      QWOOD=(SIFC*SIFS*(MIN(SIFF,SIFG)))**0.333
      VWOOD=SIFA*QWOOD
      QCROP=(SICT*SICM**2)**0.333
      VCROP=SICA*QCROP
      QGRASS=(SIGT*SIGM)**0.5
      VGRASS=SIGA*QGRASS
      VGRASSN=SIGAN*QGRASS
      VOLDF=(SIOA*SIOF)**0.5
      VOLDN=(SIOAN*SION)**0.5
      VOLDC=(SIOA*SIOC)**0.5
C
C
```

```
C ** Computes value indices for life requisites.
C
      VCOVER=MIN(1.0,(VWOOD+VOLDC))
      VFOOD=(VCROP+VOLDF+(0.1*VWOOD))
      IF(SICA.LT.1.0) VFOOD=VFOOD+MIN((1.0-SICA),(0.2*VGRASS))
      IF(VFOOD.GT.1.0) VFOOD=1.0
      VNEST=VGRASSN+VOLDN
      IF(SIGAN.LT.1.0) VNEST=VNEST+MIN((1.0-SIGAN),(0.2*VCROP))
      IF(VNEST.GT.1.0) VNEST=1.0
C
C ** Computes overall habitat value.
C
      VHAB=((VFOOD**1.5)*(VCOVER**1.5)*VNEST)**0.25
C
C ** Determines limiting factor and returns to MAIN.
C
      XLF=MIN(VFOOD,VCOVER,(1.5*VNEST))
      IF(XLF.EQ.VCOVER) LF='COVER'
      IF(XLF.EQ.VFOOD) LF='FOOD'
      IF(XLF.EQ.VNEST) LF='NESTING COVER'
      RETURN
      END
C
C ** Routine computes and returns raw and weighted interspersion
C    and juxtaposition indices.
C
      SUBROUTINE SPATIAL (HAB,SII,SIJ)
      INTEGER*1 HAB(108,108)
      INTEGER E(8)
      NEDGE=0
      NJUX=0
C
C ** Examines each pixel in section and identifies adjacent land
C    use type.
C
      DO 100 J=28,81
         DO 100 K=28,81
            E(1)=HAB(J-1,K-1)
            E(2)=HAB(J-1,K+1)
            E(3)=HAB(J+1,K+1)
            E(4)=HAB(J+1,K-1)
            E(5)=HAB(J-1,K)
            E(6)=HAB(J,K+1)
            E(7)=HAB(J+1,K)
            E(8)=HAB(J,K-1)
C
C ** Examines each adjacent or diagonal pixel separately; if
C    different type than centroid pixel, count of raw edge is
C    incremented.
C
               DO 200 N=1,8
                  NV=HAB(J,K)-E(N)
                  IF(NV.EQ.0) GO TO 200
                  NEDGE=NEDGE+1
```

```
C
C ** Determines type of edge and whether adjacent or diagonal.
C
                 KX=((E(N)**2)+(HAB(J,K)**2))
                 NX=IFIX(0.75+(0.25*N))
C
C ** Assigns weighted value to juxtaposition depending on type
C    and placement.
C
                    SELECT CASE (KX)
                       CASE(50,53)
                          NJUX=NJUX+(3.0*(FLOAT(NX)))
                       CASE(10,13,58)
                          NJUX=NJUX+(2.5*(FLOAT(NX)))
                       CASE(17,20,26,29,37,40,74,85)
                          NJUX=NJUX+(2.0*(FLOAT(NX)))
                       CASE(34,35)
                          NJUX=NJUX+(1.5*(FLOAT(NX)))
                       CASE(25,41,52)
                          NJUX=NJUX+(1.0*(FLOAT(NX)))
                       CASE(65)
                          IF(E(N).EQ.8.OR.HAB(J,K).EQ.8)
     +                    NJUX=XJUX+(0.5*(FLOAT(NX)))
                          IF(E(N).NE.8.AND.HAB(J,K).NE.8)
     +                    NJUX=XJUX+(2.0*(FLOAT(NX)))
                    END SELECT
200       CONTINUE
100   CONTINUE
C
C ** Computes mean value for weighted and raw edge.
C
      XIS=(FLOAT(NEDGE))/(2916*8)
      XJX=(FLOAT(NJUX))/(2916*12)
C
C **  Computes suitability indices for weighted and raw edge and
C     returns to MAIN.
C
      SII=1.0
      IF(XIS.LT.0.35) SII=2.857*XIS
      SIJ=XJX
      RETURN
      END
C
C ** Input routine could be developed to accommodate various
C    methods of identifying area to be modeled (MAIN program
C    requires column-row designation of extreme northwest pixel).
C    For example, coordinates could be entered directly, or the
C    township, range, and section could be entered and
C    coordinates obtained from a lookup table (this example),
C    or they could be identified by positioning cursor on a
C    graphic image display.
C
      SUBROUTINE INPUT (COL,ROW)
      INTEGER TN,RN,SE,X,Y,ROW,COL
```

```
      OPEN(UNIT=1,FILE='C:/HABMODEL/COORD.TXT',ACCESS='DIRECT',
     +RECL=16,FORM='FORMATTED')
      WRITE(*,'(A \)')' ENTER TOWNSHIP, RANGE, AND SECTION: '
      READ(*,*) TN,RN,SE
      IF(SE.EQ.6.OR.SE.EQ.7.OR.SE.EQ.18.OR.SE.EQ.19.OR.SE.EQ.
     +30.OR.SE.EQ.31) X=1
      IF(SE.EQ.5.OR.SE.EQ.8.OR.SE.EQ.17.OR.SE.EQ.20.OR.SE.EQ.
     +29.OR.SE.EQ.32) X=2
      IF(SE.EQ.4.OR.SE.EQ.9.OR.SE.EQ.16.OR.SE.EQ.21.OR.SE.EQ.
     +28.OR.SE.EQ.33) X=3
      IF(SE.EQ.3.OR.SE.EQ.10.OR.SE.EQ.15.OR.SE.EQ.22.OR.SE.EQ.
     +27.OR.SE.EQ.34) X=4
      IF(SE.EQ.2.OR.SE.EQ.11.OR.SE.EQ.14.OR.SE.EQ.23.OR.SE.EQ.
     +26.OR.SE.EQ.35) X=5
      IF(SE.EQ.1.OR.SE.EQ.12.OR.SE.EQ.13.OR.SE.EQ.24.OR.SE.EQ.
     +25.OR.SE.EQ.36) X=6
      IF(SE.GE.1.AND.SE.LE.6) Y=1
      IF(SE.GE.7.AND.SE.LE.12) Y=2
      IF(SE.GE.13.AND.SE.LE.18) Y=3
      IF(SE.GE.19.AND.SE.LE.24) Y=4
      IF(SE.GE.25.AND.SE.LE.30) Y=5
      IF(SE.GE.31.AND.SE.LE.36) Y=6
      IF(RN.EQ.6) X=X+6
      IF(RN.EQ.7) X=X+12
      IF(TN.EQ.7) Y=Y+21
      IF(TN.EQ.6) Y=Y+15
      IF(TN.EQ.5) Y=Y+9
      IF(TN.EQ.4) Y=Y+3
      IF(TN.EQ.3) Y=Y-3
      BR=((Y-1)*18)+X
      READ(1,101,REC=BR) ROW,COL
101   FORMAT(8X,2I4)
      RETURN
      END

C ** Routine to output results can be tailored to fit specific
C    needs.  Code listed here is only an example.
C
      SUBROUTINE OUTPUT (TN,RN,SE,PHH,PHA,ZF,ZC,ZW,ZG,ZO,ZN,
     +SII,LF,HSI)
      INTEGER TN,RN,SE,PHH,PHA
      CHARACTER*16 LF
      WRITE(6,101) TN,RN,SE,PHH,PHA,ZF,ZC,ZW,ZG,ZO,ZN,SII,HSI,LF
101   FORMAT(/' ',10X,'T',I1,'S R'I1,'E S'I2,';  HAMILTON CO.,'
    +'IL'//
     +' ',10X,'TOTAL AREA EVALUATED      = 259 ha (640 ac)'/
     +' ',10X,'AREA OF POTENTIAL HABITAT = 'I3,' ha ('I3,
    +'ac)'//,
     +'              WOODS -       ',F4.1,'%'/,
     +'              CROPLAND -    ',F4.1,'%'/,
     +'              WHEAT -       ',F4.1,'%'/,
     +'              GRASSLAND -   ',F4.1,'%'/,
     +'              IDLE -        ',F4.1,'%'/,
     +'              NON-HABITAT - ',F4.1,'%'//,
```

```
     +' ',10X,'INTERSPERSION INDEX = ',F4.3,/' ',10X,
     +'HABITAT SUITABILITY INDEX = ',F4.3,
     +/' ',10X,'LIMITING FACTOR IS 'A16,//)
      RETURN
      END
```

```
C
C ** Code for extracting a 0.5 mile radius circle given the X-Y
C    coordinates of the center of the circle (assumes 30 x 30 m C
C    pixels and a logical file width of 1060).
C
      FC=X-27
      FR=Y-27
      DO 100 J=1,54
         BR=(((FR-2)+J)*1060)+FC
         READ(2,REC=BR) (GIS(J,K),K=1,54)
            DO 200 KJ=1,54
               LK=IFIX((SQRT(ABS((26.8**2)-((26.8**2))))))
               KI=27-LK
               KE=27+LK
               IF(KI.LT.1) KI=1
                  DO 300 L=KI,KE
C                 .
C                 .
C                 .
300               CONTINUE
200         CONTINUE
100   CONTINUE
```

STUDY NO. 4: **Impacts of Farm Programs on Bobwhites**

JOB 4.1A(SIU): **ACR and CRP Seedings as Bobwhite Nesting and Brood-rearing Habitat**

Prepared by:

Christopher A. Meseke and John L. Roseberry
Cooperative Wildlife Research Laboratory
Southern Illinois University at Carbondale

NEED:

Prevailing land use and farming practices in Illinois do not promote the type of grasslands and early-mid successional oldfields favored by bobwhites for reproduction. Certain Conservation Practices associated with the CRP program have the potential for providing such habitat. To maximize this opportunity, specific information is needed regarding the types of seedings and plots that would most benefit bobwhites.

OBJECTIVES:

(1) To compare and evaluate various ACR and CRP seedings as bobwhite breeding habitat; and (2) establish guidelines and recommendations for selection of specific practices to best meet bobwhite breeding habitat needs in particular areas or situations.

STUDY AREA

Field studies were conducted on the Jasper County Prairie Chicken Sanctuaries (PCS), a collection of 14 separate tracts of land (7-94 ha) managed cooperatively by the Illinois Department of Conservation, the Illinois Natural History Survey, and the Nature Conservancy (Westemeier 1988). The Prairie Chicken

Sanctuaries were dedicated in 1962 for the preservation and management of the greater prairie-chicken (_Typanuchus_ _cupido_) and other endangered grassland species such as the upland sandpiper (_Bartramia_ _longicauda_) and the northern harrier (_Circus_ _cyaneus_) (Westemeier 1988).

Farming was the sanctuary's main use prior to purchase of individual tracts of land. Currently, large tracts of grasslands are managed primarily for the preservation of the greater prairie-chicken; the bobwhite is not an actively managed species.

Ten fields were selected for study based of vegetative composition and because they contained no active prairie chicken nests. Nine of the fields were located on 3 separate sanctuaries and 1 was privately owned (Table 1). Management practices on these areas reflected current land use. The 2 redtop/timothy fields were mowed yearly and the hay collected for seed. The native warm season grass fields F and I were periodically burned, while field J was both periodically burned and mowed for nesting enhancement and pheasant control. The cool season grass fields were left undisturbed. Fields B, C, E, F, H, and I, and Fields Ab, J, and N occurred in blocks of about 73 ha located < 5 km apart. Field X was located about 26 km from the other study fields. The presence of bobwhites in the general vicinity of all fields was verified from male whistling activity.

Cisne silt loam was the main soil type on the sanctuaries, with Hoyleton silt loam under only field H. Both soil types are characteristic of highly acidic grasslands and are low in organic matter. Cisne silt loam is characterized by poor drainage while

matter. Cisne silt loam is characterized by poor drainage while Hoyleton silt loam has good drainage. The general terrain is flat to gently sloping with a mean elevation of 170 m (Smith and Smith 1940). The average annual temperature for east-southeastern Illinois is 11.8 C, with a mean January temperature of -2.6 C, and a July mean of 24.8 C (Barnett 1990). Average monthly precipitation ranges from 5.49 cm in January to 10.69 cm in July, mostly in the form of rain (Barnett 1990).

Since 1966, the staff at the Prairie Chicken Sanctuaries have conducted yearly, systematic searches of areas most likely to contain prairie chicken nests. Numbers of nests of other avian species, including bobwhite, were also recorded. The number of hectares searched has declined as the number of nesting prairie chickens has declined. The number of bobwhite nests per 10 hectares declined over the past 20 years (Fig. 2). This decline may reflect a general trend in overall bobwhite abundance locally and regionally, and possibly increased competition with ring-necked pheasants, which parasitize bobwhite nests on the sanctuaries (Westemeier et al. 1989).

MATERIALS AND METHODS

Random Plot Location

Random plots (1 m^2) were located along transects in each of the 10 study fields. Each transect was parallel to the short axis of the field and crossed the long axis. Distance between transects ranged from 20 to 60 m and was selected from a random number table (Beyer 1984). Plots were randomly located along

each transect at 10 to 30 m intervals. The first plot along each transect was always placed 1 m from the field edge. A different set of plots was established during the first 2 weeks of June and July.

Nest Searches

Each study field was systematically searched at 2-week intervals by a crew of 3-5 people spaced at approximately 1-2 m intervals. Nest searching began on 4 June 1990 and was completed on 3 August 1990. All fields were searched 5 times. Each nest found was marked with flagging tape 15 m north and east to avoid attracting predators. Nests were monitored every 3-4 days until their final fate was known (abandoned, empty, hatched, or predated). Nests were uniquely identified with the letter of field, date of location, and a nest number (e.g. B60401 identified the first nest found on 4 June, in field B). The direction of nest entrance, number of eggs present, and number of eggs hatched were recorded for each nest.

Variables Measured

The following variables were measured at each nest site and random field plot: percent canopy cover of dominant grasses and forbs, percent litter cover, percent bare ground, standing vegetation density, and vegetation weight using the Robel "visual obstruction reading" (VOR) (Robel et al. 1970a). Estimated standing vegetation density, percent canopy cover of grasses and forbs, bare ground, and litter were categorized as 0-5%, 6-25%, 26-50%, 51-75%, 76-95%, and 96-100% (Daubenmire 1959, Robel et

al. 1970*b*). Mean percentages were calculated by multiplying the number of occurrences in a particular category by the midpoint of each category. Values for the 6 categories were then divided by the number of plots of occupance. Vegetation weight and plot density were determined using the Robel "visual obstruction reading" (VOR). A 1 m pole, marked in centimeters, was placed upright in the ground at the north edge of each plot. The pole was viewed from a distance of 3 m and a height of 1 m to the lowest completely visible cm. This number was converted into decimeters and entered into the regression equation $Y = 1.9 + 113X$ to estimate vegetation weight (Robel et al. 1970a). Density was defined as the amount vertical of screening (percent coverage of the marked pole), and was used as an indication of the amount of open space at "bird" level.

Data Analysis

Random plot data from individual fields were pooled and compared to nest site data to test for homogeneity of variance (F test) and equality of means (Z test). Chi-square analysis was used to determine the homogeneity of distribution of nest site values above or below their respective field means. Nest opening orientation and cover type were analyzed using a Chi-square test of homogeneity (Zar 1984).

Factors potentially related to nest site selection were analyzed using Principal Component Analysis (PCA). This ordination technique summarized the community data by producing a small dimension ordination in which similar samples were close together and dissimilar samples far apart (Gauch 1989). The

variables vegetation weight (VOR), age of field (AGE), percent bare ground (BARGRND), percent litter cover (LITTER), vegetation density (DENSITY), canopy coverages of the most frequent cool season grass (CLGR1CAN), the second most frequent cool season grass (CLGR2CAN), the most frequent warm season grass (WSGR1CAN), the second most frequent warm season grass (WSGR2CAN), multiflora rose (MFRCAN), briars (BRIARCAN), and goldenrod (GOLDCAN). The component scores from the PCA were then correlated (Pearson's r) with the number of nests per ha. SYSTAT (ver. 5.0) was used for data storage and statistical analysis (Wilkinson 1990). Scientific names of plants mentioned in this report are given in Appendix A.

RESULTS AND DISCUSSION

Nest Density and Fate

Twenty-one bobwhite nests were found during the 10-week search period, or 1 nest per 1.5 hectares. The nest density was higher than the 1 nest/4.2 ha reported by Klimstra and Roseberry (1975) over an 11-year period near Carbondale, Illinois or the 1 nest/9.1 ha recorded on the PCS over a 20 year period (R. Westemeier, pers. comm). It is difficult to compare nest densities among these studies, however, because of important difference in frequency, timing, and intensity of searching efforts. We searched individual fields 5 times compared to only 1-4 times for the other studies. Also, the PCS was usually searched only during April and May.

Of the 21 nests found, 5 (24%) hatched, 4 (19%) were abandoned, 8 (28%) were predated, and 4 (19%) were empty.

nest success was 29%. Other studies have reported bobwhite nest success rates of 23, 34, and 36% in Tennessee, southern Illinois, and Georgia-Florida, respectively (Dimmick 1968, Klimstra and Roseberry 1975, Stoddard 1931).

Mean size of the 5 completed clutches was 15.6 eggs (range 13-21). This figure is somewhat higher than the 13.7 reported by Klimstra and Roseberry (1975) for 388 nests in southern Illinois but the disparity in sample sizes precludes meaningful comparisons.

Nest Site Selection

Among Fields and Vegetative Types.--Nest densities differed among individual fields ($0.10 > P > 0.05$) and vegetative types ($P < 0.05$). Fields B (brome grass) and F (native grasses) contained more nests than expected based on availability whereas Fields N (redtop/timothy) and X (oldfield) contained fewer (Table 2). When fields were grouped by vegetative type, more nests than expected were located in native warm season grass fields and fewer than expected in redtop/timothy mixtures (Table 3).

More than 83% of the total variance in the vegetational and structural variables across all fields and nests was accounted for by the first 3 principal components (Table 9). Principal component I (PC I) was a gradient based on physical site variables and explained approximately 36% of the variance among samples. PC II, which explained 32% of variance, was a canopy coverage gradient of the 2 most dominant grasses per field (cool season or warm season) and age of field. PC III represented a gradient of canopy coverage of goldenrod and multiflora rose and

explained 15% of variance.

Principal Components Analysis provided a useful summary of the field data. A plot of the first 2 principal components (PC I and PC II) segregated individual fields based on predominant vegetative type, i.e., brome grass, native warm-season, and redtop/timothy fields generally clustered together (Figure 3). An exception was the 2 oldfields (E and X). Both fields were classified as oldfield/successional cover types and contained vegetation with similar canopy characteristics, therefore they plotting closely on PC II. The separation on PC I was primarily caused by a difference in field means for VOR-vegetation weight, bare ground, litter, and density. Different values for these variables probably reflected the origins and past management of these fields. Field E was 6 years old at the time of our study and had resulted from a failed redtop-timothy seeding in a prior soybean field. It was in the perennial weed stage of succession and had been mowed 2 years previously. In contrast, Field X was an abandoned pasture that had not been disturbed in 9 years nor actively managed for 15 years. The fields also differed in vegetational composition. The predominant vegetation in Field E was cool-season grasses (redtop, fescue, brome grass) and briars. In contrast, Field X was dominated by fescue and goldenrod and contained much less bare ground than did Field E.

There was a significant ($\underline{r} = -0.723$, 9 df, $\underline{P} < 0.05$) negative correlation between PC II and the number of nests per hectare (Fig. 4). This plot also showed a grouping of the fields by cover type. Although accounting for a combined 69% of the

variance in the data, neither PC I nor PC III were correlated with the number of nests per hectare (*r* = -0.299, 9 df, *P* > 0.20 and *r* = -0.01, 9 df, *P* > 0.20, respectively).

The absence of a relationship between PC I and nest density suggests that physical site variables at the nest site (such as bare ground or litter), while important to nest site selection, may not be as important as canopy coverage. Too little canopy coverage may be detrimental as it may allow too much exposure to heating and predators. Too much canopy may also be detrimental to thermoregulation of the eggs, and restrict access to the nest.

Native warm-season grasses (NWSG) are generally considered to be superior to introduced cool-season grasses as bobwhite nesting habitat (George et al. 1979, Burger et al. 1990, Clubine 1991). Our study corroborated this opinion as bobwhites on the PCS study areas appeared to selectively nest in areas dominated by NWSG. The primary attraction of this vegetative type for nesting bobwhites is the characteristic bunch-type growth pattern with interstitial areas of bare ground or light litter. Periodic burning is necessary, however, to keep NWSG from becoming too rank for bobwhite (Clubine 1991). The utility of NWSG as brood habitat is enhanced by increasing the annual and perennial forb component.

Another vegetative type favored by nesting bobwhites is represented by certain oldfields. Klimstra and Roseberry (1975:17) characterized preferred successional cover as: ". . . scattered shrubs and briars interspersed with a moderately dense stand of herbaceous and grassy vegetation such as goldenrods,

panic grasses, cheat, broomsedge, and bluegrass." They noted, however, that "cover too uniformly thick to allow the birds some access to bare or nearly bare ground usually was avoided." Prime nesting conditions generally prevail during the late perennial weed and early shrub and bramble stages of secondary succession. Later stages are often dominated by woody vegetation which shades out preferred grasses while earlier stages have too little residual vegetation for nest construction. For this reason, annual set-aside acreage (Acreage Conservation Reserve or ACR) does not generally provide suitable bobwhite nesting cover. Such areas, as well as early CRP plantings and oldfields in the annual weed stage do, however, often provide suitable brood rearing habitat (Burger et al. 1990). The original cover type from which oldfields succeed is very important in determining subsequent vegetative composition and structure and therefore habitat potential. Preferred conditions generally occur when succession proceeds from intertilled cropland or other bare ground situations. Abandoned fescue pastures, however, often maintain a vigorous fescue component for many years that retards invasion of more suitable vegetation. These areas lack the bare ground necessary for good bobwhite nesting and brood-rearing habitat. Field X in our study offered a prime example of this situation. Although technically classified as an oldfield, the area was dominated by a thick fescue understory and was not utilized by nesting bobwhites even though whistling males were present in the general vicinity.

Neither NWSG or typical oldfield vegetation is common on CRP

lands in Illinois, approximately 87% of which is in CP-1 (introduced cool-season grasses/legumes) contracts. On CP-1 lands, orchard grass and timothy were the most commonly planted grasses followed by smooth brome grass, redtop, and tall fescue. The most popular legumes were alfalfa, Korean lespedeza, ladino clover, and red clover (Roseberry and David 1992). Orchard grass and smooth brome grass were most commonly combined with a legume whereas tall fescue often appeared as a monoculture. Timothy and redtop were often planted in a mixture with Korean lespedeza. Of these mixtures, only the latter is generally considered to be potentially useful as bobwhite nesting habitat (Klimstra and Roseberry 1975, Martin 1988). On the PCS, use of brome grass fields was consistent with their availability but red top/timothy fields were used less than expected. Orchard grass fields did not occur on the PCS and thus could not be evaluated. The relatively poor utilization of the red top/timothy fields in comparison to the smooth brome fields was attributed to the fact that the former were mowed annual whereas the latter were undisturbed.

Within Fields.--Vegetation at nest sites tended to be representative of general field conditions. Across all fields, the most common plants at nest sites were briars, sedges, big bluestem, goldenrods, and switchgrass (Table 3). Fescue occurred at 5 of 21 nest sites (24%) but was not represented by monocultural stands and did not account for a large portion of the vegetation at any nest site.

Due to problems encountered in the collection of certain

vegetative structure variables, we were unable to conduct planned evaluations of within-field nest site selection.

CONCLUSIONS AND RECOMMENDATIONS

The following are based on general knowledge, a review of the literature, and results from this study.

1. Prime brood rearing cover tends to be more open at ground level than nesting cover and therefore often represents earlier successional stages or more recent CRP fields.
2. Bobwhite reproductive opportunities on CRP land are maximized when both brood rearing and nesting cover is provided. This can be accomplished by strip discing the field periodically, burning portions of the field on a rotational basis, or broadcasting grass seed so that there are alternating strips of grassy and weedy vegetation.
3. Native warm season grasses are preferred over cool season grasses as bobwhite habitat and their use should be encouraged.
4. If cool season grasses are used, redtop/timothy is preferred and tall fescue should be avoided. This study did not compare smooth brome and orchard grass.
5. Including legumes in initial grass seedings or subsequent interseedings can increase diversity and insect abundance for brood habitat. However, dense stands of alfalfa or red clover are not conducive to bobwhite nesting and may be too thick for brood movement.
6. Annual and perennial forbs should be encouraged by either incorporating native legumes in CP-2 seedings or strip discing alternating portions of the field at about 3 year intervals.

7. Mowing, especially during the peak nesting season (mid-May through mid-August) should be avoided.

8. Nesting/brood rearing cover will not be the limiting habitat component in every situation. When winter food is limiting, incorporation of food plots into CRP fields and use of Korean lespedeza should be encouraged.

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Table 1. Study fields at the Jasper County Prairie Chicken Sanctuaries, Illinois, Summer 1990.

Area	Field	Size (ha)	Age (Years)	Management	Predominant Cover Type
Mark 17 and[a] 40 Sanctuaries	B	2.02	10	undisturbed	smooth brome grass
	C	3.24	5	undisturbed	smooth brome grass
	E	2.83	5	undisturbed	old field
	F	2.83	19	January burn 2 years ago	native warm-season grasses
	H	2.83	4	mowed	redtop/timothy
	I	2.02	18	February burn 3 years ago	native warm-season grasses
Otis Sanctuary[b]	Ab	2.02	7	undisturbed	smooth brome grass
Fuson Farm[c]	J	4.05	18	mowed/February burn 3 years ago	native warm-season grasses
	N	6.88	2	mowed	redtop/timothy
Simpson Farm[d]	X	2.02	8	undisturbed	old field

[a] T6N, R9E, S23.
[b] T6N, R9E, S29.
[c] T6N, R6E, S29,30.
[d] T8N, R10E, S6.

Table 2. Selection of individual fields by nesting bobwhites, Jasper County Prairie Chicken Sanctuaries, Summer 1990.

Field	Type	Size (ha)	Number of Nests Observed	 Expected	X^2
B	Brome grass	2.02	3	1.38	1.90
C	Brome grass	3.24	2	2.21	0.02
E	Oldfield	2.83	2	1.93	0.00
F	Native grasses	2.83	6	1.93	8.58
H	Redtop/timothy	2.83	1	1.93	0.05
I	Native grasses	2.02	2	1.38	0.28
J	Native grasses	4.05	3	2.77	0.02
N	Redtop/timothy	2.02	1	1.38	0.10
Ab	Brome grass	2.02	1	1.38	0.10
X	Oldfield	2.02	0	1.38	1.38
Total		30.75	21	21.00	15.25[a]

[a] df = 9, $0.10 > \underline{P} > 0.05$

Table 3. Selection of cover types by nesting bobwhites, Jasper County Prairie Chicken Sanctuaries, Summer 1990.

Cover Type	Area Searched (ha)	Number of Nests Observed	Number of Nests Expected	X^2	Nests/ha
Brome grass	7.28	6	4.99	0.21	0.82
Redtop/timothy	9.71	2	6.65	3.25	0.21
Oldfield	4.86	2	3.33	0.53	0.41
Native grasses	8.90	11	6.10	3.94	1.24
Total	30.75	21	21.00	7.93[a]	0.67

[a] df = 3, $P < 0.05$.

Table 4. Frequency of occurance of vegetative types at bobwhite nest sites, Jasper County Prairie Chicken Sanctuaries, Summer 1990.

Vegetative type	Number	Percent
Briars	9	42.9
Sedges	9	42.9
Big bluestem	8	38.1
Goldenrods	8	38.1
Switchgrass	8	38.1
Smooth brome grass	6	28.6
Fescue	5	23.8
Indian grass	5	23.8
Rushes	4	19.0
Bluegrasses	3	14.3
Timothy	2	9.5
Redtop	2	9.5
Little bluestem	1	4.8

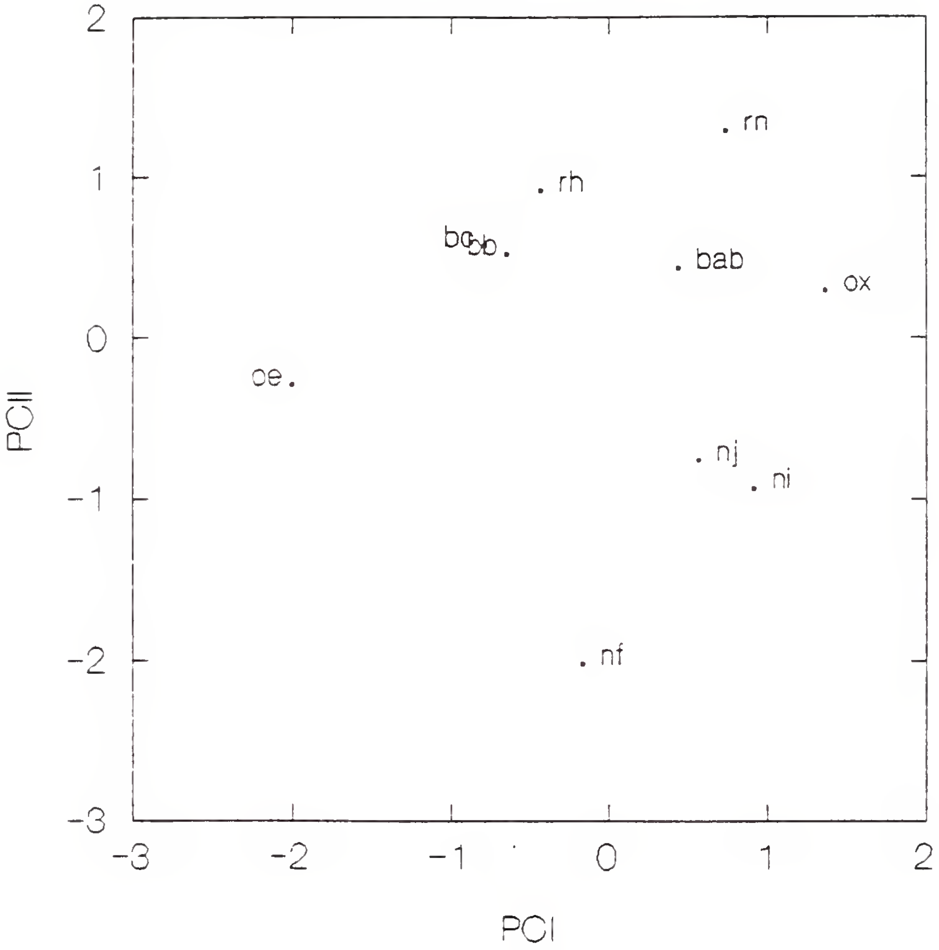

Figure 1. Location of study fields with respect to the first and second principal components (PCI and PCII). The first letter indicates cover type (b=brome, n=native grass, o=oldfield, r=redtop) and the second letter identifies the field.

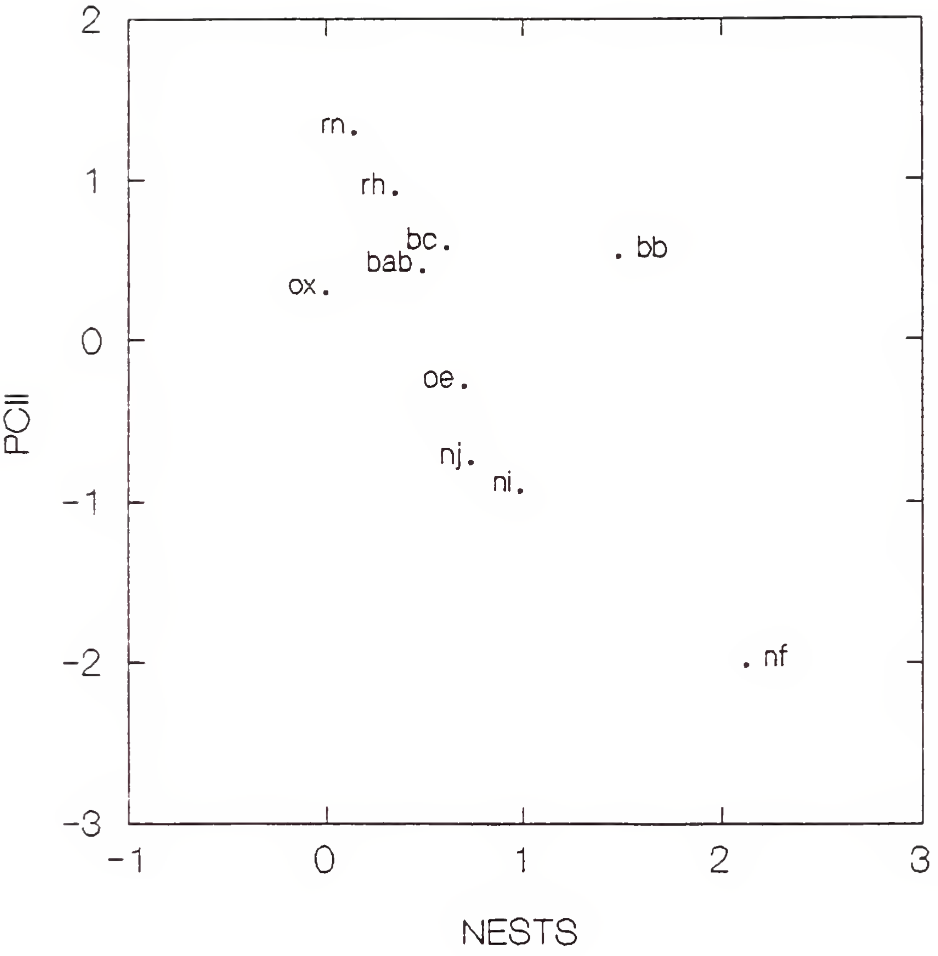

Figure 2. A plot of nest density on Principal Component II (See Figure 1 for field and cover type designations).

Appendix A. Scientific names of plants mentioned in this report.

Common Name	Scientific Name
Alfalfa	Medicago sativa
Big bluestem	Andropogon gerardii
Bluegrass	Poa spp.
Briars	Rubus spp.
Broomdsedge	Andropogon virginicus
Cheat grass	Bromus secalinus
Fescue	Festuca spp.
Goldenrod	Solidago spp.
Indian grass	Sorghastrum nutans
Korean lespedeza	Lespedeza stipulaceae
Ladino clover	Trifolium repens
Little bluestem	Schizachyrium scoparium
Multiflora rose	Rosa multiflora
Orchard grass	Dactylis glomerata
Panic grass	Panicum spp.
Red clover	Trifolium pratense
Redtop	Agrostis alba
Rush	Juncus spp.
Sedge	Carex spp.
Smooth brome grass	Bromus inermis
Switch grass	Panicum virgatum
Timothy	Phleum pratense

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